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BIOLOGICAL SCIENCES

MYCOBIOTA OF SELECTED MEDICINAL PLANTS IN THE GADABAY REGION (AZERBAIJAN): TAXONOMIC STRUCTURE AND ECOLOTROPHIC CHARACTERISTICS

Fidan Mammadova
Department of Biology, Baku State University, Baku, Azerbaijan
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Abstract

Medicinal plants constitute an essential component of traditional and modern medicine; however, their therapeutic value may be significantly compromised by microbial and fungal contamination. Although numerous studies worldwide address mycobiota associated with medicinal plants, region-specific investigations in Azerbaijan remain scarce. This study aimed to assess the diversity, taxonomic structure, and ecolotrophic roles of microscopic fungi colonizing selected medicinal plants-*Urtica dioica* L., *Stellaria media* L., and *Cephalaria gigantea* (Ledeb.) Bobrov-naturally growing in the Gadabay region. Mycological analyses were conducted using standard cultivation, microscopic, and statistical methods. More than 15 species of micromycetes were isolated and identified. Fungi belonging to the phylum **Ascomycota** dominated the mycobiota (66%), while **Zygomycota** accounted for 34%. The most frequently encountered genera included *Aspergillus*, *Penicillium*, *Alternaria*, *Fusarium*, *Mucor*, and *Rhizopus*. Plant-fungal interactions were classified into parasitic, saprotrophic, and occasionally mutualistic relationships. Pathogenic species were predominantly associated with senescent, stressed, or mechanically damaged plant tissues. The findings emphasize the necessity of mycological monitoring to ensure the hygienic quality and biological safety of medicinal plant raw materials.

Keywords: medicinal plants; mycobiota; micromycetes; fungal contamination; plant-fungal interactions

1. Introduction

Medicinal plants have been widely used for centuries as natural remedies due to their rich content of biologically active compounds and relatively low toxicity compared with synthetic pharmaceuticals. In recent decades, global interest in herbal medicine has increased substantially, driven by a growing preference for natural products and sustainable healthcare solutions. Azerbaijan, particularly its mountainous regions, possesses significant floristic diversity and a long tradition of medicinal plant use (Aslam et al., 2025; Ahmadov, 1984; Ibadullayeva 2001; Gasimov, Aliyev, 1998).

The Gadabay region, located in the Lesser Caucasus, is characterized by diverse ecological conditions that support numerous medicinal plant species. Despite their therapeutic potential, medicinal plants are highly susceptible to microbial contamination during growth, harvesting, drying, storage, and processing. Among microorganisms, microscopic fungi represent one of the most critical groups affecting plant quality, safety, and pharmacological efficacy.

The objects of these investigations are microscopic fungal species (mycoflora) distributing on some medicinal plants (*Urtica dioica* L., *Stellaria media* L., *Cephalaria gigantea* (Ledeb.) Bobrov) in the natural conditions of the Gadabay region.

Micromycetes may colonize plant surfaces or internal tissues, leading to tissue degradation, reduction of active metabolites, and production of toxic secondary metabolites such as mycotoxins (Namazov & Sultanova, 2015). These fungi not only pose phytopathological risks but may also threaten consumer health if contaminated plant materials are used for medicinal purposes. Consequently, understanding the composition and ecological behavior of fungal communities associated with medicinal plants is essential for quality control and biosecurity (Mammadova, 2025).

Although mycological investigations of medicinal plants have been widely conducted in Europe and Asia, regional studies focusing on Azerbaijan's native flora remain limited. In particular, the mycobiota associated with medicinal plants growing under natural conditions in the Gadabay region has not been systematically studied. Therefore, the present research aims to fill this knowledge gap by characterizing the taxonomic diversity and ecolotrophic structure of fungi colonizing selected medicinal plant species.

2. Materials and Methods

2.1 Study Area

Gadabay district, known for its natural beauty, rich history and culture, is one of the charming corners of Azerbaijan. It is located in the high and middle mountainous belts of the Lesser Caucasus, in the area bordering the Gazakh and Tovuz districts in the west of Azerbaijan. Its area is 1232.98 square kilometers and is considered one of the ancient settlements of Azerbaijan. Goshabulag and Gojadagh are considered the highest peaks, as Goshabulag is 3549 m, and Gojadagh is 3317 m. Anthropogenic, Jurassic, Cretaceous and Paleogene sediments are mainly distributed here. White and black marble deposits are mainly found in the deposits.

The climate is typical of a mountainous region, as a mild subtropical climate prevails in the lower parts of the region, but colder climatic conditions prevail as the altitude increases. High mountainous areas receive a lot of snowfall. A cold, dry, mountainous tundra climate prevails in winter. A mild, dry, warm climate prevails in summer. The air temperature in July is 10°C-20°C, and in January -2°C-10°C. Mountain-forest lands are observed in mountainous areas with a mild-warm climate between 700-200 m.

Yellow, black, brown and brown soils are found. Brown soils have developed under moist forests rich in rot. Brown soils are found in forests with a relatively dry climate. Yellow soils are widespread in the Talysh Mountains and Lankaran Lowland. The soil is red and yellow due to the iron it contains. A very dense river network is found. The upper reaches of the Akhinja and Zayam rivers are located in this region, and the upper reaches of the Shamkir river are located on the southwestern border of the region. One of the most important water sources is the Gamarli river. It is provided with various lakes and small reservoirs suitable for irrigation. The Tartar River is located in the southern part of Gadabay and is used for irrigation purposes. There are various mountains and mountainous valleys in the region. The most famous of these are the Gadabay Mountains, Murovdag and the Tartar River Valley (Climate atlas of the Republic of Azerbaijan, 1992).

2.2 Plant Material

Three medicinal plant species widely used in folk medicine were selected as study objects: *Urtica dioica* L., *Stellaria media* L., and *Cephalaria gigantea* (Ledeb.) Bobrov. Plant samples were collected from two natural sites within the Gadabay region during the vegetative period. Healthy and visibly affected plant organs were sampled to assess fungal diversity under different physiological conditions.

2.3 Fungal Isolation and Identification

Fungal isolation was carried out using standard mycological techniques. Plant fragments were aseptically placed on YGC (Yeast Extract Glucose Chloramphenicol) and DG18 (Dichloran Glycerol) agar media and incubated at 25–27 °C. Colony development was monitored daily, and pure cultures were obtained through subculturing.

Identification was based on macroscopic characteristics (colony morphology, pigmentation, growth rate) and microscopic features (conidia, hyphae, sporulation structures) using light microscopy. Taxonomic identification was performed according to international mycological keys and reference databases.

During the cultivation method of fungi, a number of equipment and supplies, nutrient media are used in the laboratory. When choosing a nutrient medium, it is necessary to know in which nutrient medium the fungi develop. When preparing the nutrient medium, an accurate weighing scale, a flask or a Pyrex bottle, a magnetic stirring oven, distilled water and powdered nutrient media were used. Ready-made YGC (Yeast Extract) and DG18 (Dichloran-Glycerol) agars were used as nutrient media. After weighing 22.5 g of YGC and DG18 agars with 1L of distilled water accurately on a scale and pouring them into the flask, distilled water is measured using a beaker and added to the flask. After being placed on a magnetic stirrer for good mixing, it is autoclaved. The prepared sterile nutrient media are poured into petri dishes in a completely sterile manner in a UV box. The sample is separated using tweezers and sterilely taken and placed in a petri dish. A control (witness sample) is placed in the nutrient medium to ensure that no fungi fall from the outside and there is no external contamination. Then it is placed in an incubator at 25-27˚C. The full development of the fungi is possible within 5 days. It is necessary to make sure that the incubators are working properly within 5 days. For this, the temperatures of the incubators should be measured and recorded every day. The development of the fungi is monitored from the 3rd day. The colonies that develop should be removed to a clean environment and the type determined.

After the colony is placed on a slide, it is examined under a microscope using the Gram stain method and the type is determined. For this, the database of the International Association of Mycology, as well as the CBC fund, is used.

It is possible to determine whether the growth and development of mushroom species differ by the Growth Factor. The Growth Factor is based on a special formula: D is the diameter of the colony (measured in millimeters), H is the vertical size (height) of the colony, S is the density indicator of the colony (evaluated on a scale from 1 to 5), and T is the cultivation period (in days).

The systematic location of plant species and their distribution frequency were calculated using the following formula:

$$N = n / s$$

Where, N is the frequency of use (units/ha), n is the number of specific medicinal plant species observed in a given area, and s is the total area of the studied area (in hectares).

The frequency of occurrence of fungal species in samples and the prevalence of diseases caused by pathogenic microorganisms were determined using the following formula:

$$P = (n / N) \times 100$$

Where, P is the frequency of detection of fungal species in samples or the prevalence of diseases caused by pathogens (in %), n is the number of specific fungal samples (plant individuals carrying the disease) observed, and N is the total number of plant samples studied in general."

The experiments were repeated at least three times, and the results obtained were analyzed using statistical methods. Only indicators that correspond to the formula

$$m/M = P \leq 0.05$$

Where M is the average value, m is the standard deviation, P is the probability level estimated by the Student test were considered reliable and included in the dissertation [14].

2.4 Statistical Analysis

The frequency of fungal occurrence and plant colonization was calculated using standard ecological indices. All experiments were conducted in triplicate, and statistical reliability was assessed using Student's *t*-test, with significance accepted at $P \leq 0.05$.

3. Results

A total of more than 15 species of microscopic fungi were isolated from the investigated medicinal plants. These species were classified into two major phyla: **Ascomycota** and **Zygomycota.** Ascomycetous fungi represented the dominant group, accounting for approximately two-thirds of the identified taxa.

Within Ascomycota, members of the genera *Aspergillus* and *Penicillium* were particularly abundant. Zygomycetous fungi were represented mainly by *Mucor*, *Rhizopus*, and *Syncephalastrum*. The detected fungal taxa displayed distinct colony morphologies and growth patterns, reflecting their ecological adaptability.

4. Discussion

The dominance of Ascomycota in the mycobiota of medicinal plants is consistent with findings from other geographical regions. Many species of *Aspergillus* and *Fusarium* are known for their phytopathogenic potential and ability to produce mycotoxins, which may compromise the safety of medicinal plant materials.

In recent years, plant-microbiome studies have become of great importance in terms of studying biodiversity and establishing sustainable agricultural systems. Microorganisms living on and inside plants, especially microscopic fungi are directly related to the development, stress resistance and metabolic activity of plants. They play various ecolotrophic roles and interact with plants as symbionts, pathogens or saprotrophs.

Saprotrophic fungi are fungi that live on and feed on dead and decaying matter. They play a very important role by breaking down dead organisms and ensuring the recycling of substances. Pathogenic fungi, unlike saprotrophic representatives, live on living organisms and cause crop losses in agriculture, as well as a number of serious diseases. Symbiont fungal species live together with other organisms and provide mutual benefit (mutualism). That is, the fungal organism transfers water and minerals from the soil to the plant. The plant transfers sugars produced as a result of photosynthesis to the fungus. Symbiont forms include mycorrhiza and symbionts.

During their long historical evolution, fungi have acquired adaptations and adaptations to environmental conditions, which have resulted in the formation of ecological groups. Therefore, they have formed various biologically active substances such as antibiotics, mycotoxins, vaccines, etc. They also play a significant role in the mineralization and biochemical transformation of dead organisms and living remains in the soil, in increasing soil fertility, and in soil formation.

The soil ecological group is a favorable habitat and food source. It is considered the main ecological environment for fungi. Gadabay region, one of the high mountainous zones of Azerbaijan, has a rich floristic diversity and various medicinal plants are distributed here in natural conditions. The mycobiota formed on these plants is important both in terms of maintaining ecological balance and in terms of medical and agrobiotechnological potential.

The ecolotrophic approach allows for the assessment of the ecological position and food acquisition strategies of fungi together. Within the framework of this study, fungi participating in the mycobiota of medicinal plants found in the flora of the Gadabay region were divided into parasitic, saprotrophic, symbiont, and endophytic groups.

The aim of this study is to determine and evaluate the composition of mycobiota formed on selected medicinal plants growing in the Gadabay region and the ecolotrophic functions (parasitism, saprotrophism, symbiosis, and endophytism) of these fungi.

Fungi identified in this study exhibited diverse ecolotrophic strategies. Saprotrophic species played a role in organic matter decomposition, while parasitic fungi were associated mainly with weakened plant tissues. Mutualistic or endophytic interactions were less common but may contribute to plant stress tolerance and metabolic activity (Namazov, 2019).

Environmental factors, plant age, and tissue integrity were found to influence fungal colonization patterns. These observations highlight the importance of ecological conditions in shaping plant-associated mycobiota.

5. Conclusions

The present study reveals that medicinal plants growing in the Gadabay region harbor a diverse and ecologically complex mycobiota dominated by Ascomycota. Pathogenic and saprotrophic fungi prevail, particularly in stressed or damaged plant tissues. These findings underline the importance of continuous mycological monitoring and strict hygienic measures during the harvesting, drying, and storage of medicinal plants to ensure their safety and therapeutic quality.

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ECONOMIC SCIENCES

OVERVIEW OF ACCESS TO FINANCING FOR ENERGY EFFICIENCY AND SOLAR ENERGY TECHNOLOGIES FOR SMES IN GEORGIA

Tamar Gamsakhurdia
Prof., Grigol Robakidze University, Georgia
Natia Daghelishvili
Prof., Grigol Robakidze University, Georgia
Giga Tvauri
Asist. Prof., Grigol Robakidze University, Georgia
Ketevan Maisuradze
Assistant., Grigol Robakidze University, Georgia
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Abstract

Small and Medium Enterprises (SMEs) play a pivotal role in the sustainable development of the economy. The implementation of energy efficiency and solar energy technologies not only reduces operational costs but also contributes to environmental and economic sustainability. Access to financing for integrating these technologies presents several challenges. This research aims to examine the current state of financing for energy efficiency and solar energy technology implementation for SMEs in Georgia and to develop recommendations for stimulating mechanisms in this direction. To achieve the study's objectives, a mixed-methods approach was adopted. The qualitative research included desk research on foreign and Georgian publications, as well as legislative and policy documents related to energy efficiency and solar energy investments. The quantitative research involved structured interviews with top management of Georgian banks and field professionals. Additionally, a survey was conducted among government organizations, industry associations, and companies utilizing solar power plants. This also included in-depth group interviews with solar power system installers to identify challenges in implementing these technologies for SMEs.

The research analyzed the barriers and opportunities for SME financing, developed recommendations for necessary reforms to support relevant government agencies, and aimed to enhance the activities of international financial and specialized organizations, as well as commercial banks, in promoting investments and financing in energy efficiency and solar energy projects for SMEs.

Keywords: SMEs, Energy Efficiency, Solar Energy, Financing, IFIs, Georgian Banks, Green Loans, Renewable Energy.

Relevance of the Topic

In Georgia, as well as globally, SMEs play a significant role in the sustainable development of the economy (Tsutskiridze et al., 2024; Tsutskiridze, Charaia, 2023). They account for 67% of employment and approximately 62% of the total value added, making their impact on the environment substantial. SMEs are considered the backbone of the economy, and their development is important for any country in two ways: firstly, in terms of increasing national welfare, which includes reducing social and financial inequality, and secondly, in terms of reducing environmental impact. While the effect of individual enterprises is small, their total number surpasses that of large enterprises. Reducing energy intensity in SMEs will have a significant impact on the country's economic and ecological efficiency. The 2021-2025 Strategy for the Development of Small and Medium Enterprises in Georgia has identified improving access to finance as a priority, with the seventh priority being the promotion of green economy development.

Significant funds have been allocated at the national level to implement sustainable development and climate change measures in Georgia, directed both towards green financing (energy efficiency, renewable energy sources) and towards creating a market for green goods and services (specifically, energy-efficient construction products). Green technologies are characterized by high costs and 90% are imported from abroad. According to the World Bank's 2019 Enterprise Survey, access to finance is cited as the second-largest obstacle after instability. This is confirmed by data from the National Bank of Georgia's Credit Conditions Survey (NBG. Credit Conditions Survey, p.7, 2024).

According to the data available to the National Bank, the interest rates on national currency loans did not change (Anguridze et al., 2015), and amounted to 13.2% for SME loans. For SME loans issued in euros, the interest rate declined by 0.3 percentage points to 7.0%. For USD-denominated loans, the interest rate slightly decreased to 8.4%. In the first quarter of 2024, the share of rejected loans did not change significantly. Compared to the previous quarter, the share of rejected loans in SME loans issued in national currency remained at 20%, while for foreign currency SME loans, the share of rejected loans declined to 9% (NBG. Credit Conditions Survey, p.8, 2024).

The data presented by NBG allows us to conclude that the interest rates on SME loans have been higher compared to those for large enterprises since May 2021, though they have matched the rates for large companies by the third quarter of 2023. This is a positive trend but remains a hindrance from the

perspective of SME development. Regarding rejected applications for SMEs, the number is relatively high and increasing.

When analyzing the structure of investment costs for SMEs, 70% is covered by internal resources, with bank credit coming in second. The situation has not significantly improved since 2013 when the share of SME funds was 73%-75%. High collateral requirements are a major obstacle in the crediting process, with collateral requirements amounting to 191% for SMEs and 195% for medium-sized enterprises (Ministry of Economy and Sustainable Development of Georgia, 2021).

Thus, SMEs play a decisive role in the sustainable development of the economy (Sikharulidze, Charaia, 2018; Lashkhi et al., 2022a; 2022b). The process of implementing energy efficiency and solar energy technologies not only reduces operational costs but also promotes environmental and economic sustainability. It is undeniable that access to financing for integrating these technologies is fraught with difficulties.

All of the above defines the relevance of the issue, with the aim of the research being to examine the current state of financing for energy efficiency and solar energy technologies for SMEs in Georgia, identify barriers, and develop recommendations for stimulating mechanisms in this area.

Research Design

Based on the research aim, the following objectives are set:

- Examine barriers and opportunities for SME financing at various developmental levels, both globally and in Georgia.
- Identify necessary reforms to support government structures and determine the role of international organizations in promoting investments and financing for energy efficiency and solar energy projects for SMEs.
- Analyze the activities undertaken by Georgian financial institutions in this regard.

The target groups of the research include:

- Various financial institutions (international organizations, international financial institutions, Georgian banks).
- Representatives of companies that have utilized credit, as well as representatives from companies, associations, and government institutions involved in the process.
- Government agencies.

The research methods employed to achieve the goals and objectives of the study include both qualitative and quantitative approaches. Qualitative methods comprised in-depth interviews and desk research, which involved analyzing existing foreign and Georgian publications and legislative-policy documents related to investments and financing in energy efficiency and solar energy projects.

Quantitative methods were used to identify problematic issues related to the implementation of energy-efficient and solar energy technologies for SMEs. A structured interview was conducted with professionals in the field, and a survey was carried out involving sector-specific entities, including government organizations, associations, companies engaged in the installation of solar power systems, and companies that use solar power plants.

Literature Review

Access to financing for integrating energy-efficient technologies is characterized by challenges. Therefore, it is important to discuss the main barriers and opportunities faced by SMEs in financing these technologies in different countries. This literature review aims to examine contemporary financial mechanisms tailored to SMEs for adopting sustainable energy solutions.

The review of literature related to the research topic highlights the barriers encountered by SMEs when accessing financing for energy-efficient and solar energy technologies:

High Investment Costs and Collateral Requirements: These technologies generally require substantial upfront capital investments (Smith et al., 2022), which financial institutions often require significant collateral to secure, posing an insurmountable barrier for many SMEs (Sheikh et al., 2019), despite their long-term savings (Gupta & Barua, 2018).

Information Asymmetry and Lack of Technical Expertise: The limited availability of information about financing options and the benefits of energy-efficient and solar energy technologies can be a significant impediment to decision-making (Jones & Lee, 2018; Bullier & Milin, 2013).

Perceived Risk: Lenders may perceive SMEs as higher-risk businesses, leading to stricter credit criteria and higher interest rates for renewable energy projects (Gupta & Barua, 2018; Wishlade, Michie, & Vernon, 2017).

Complex Application Procedures: The loan application process is often lengthy and labor-intensive, which hinders financing (Dupont & Oberthür, 2015). Recent studies also confirm this challenge and emphasize the need to address the issue.

Political and Regulatory Uncertainty: Inconsistent policies, ambiguous regulations, and unstable market conditions create uncertainty that hinders financial institutions from investing in renewable energy projects for SMEs (Brown & Morrad, 2020). Stable policy frameworks and clear regulatory guidelines are essential for encouraging private sector investments in sustainable energy projects, especially under the challenging circumstances, such as a Coronomic crisis (Papava, Charaia, 2020; 2021; 2022), governmental debt management challenges (Charaia, Papava, 2021; Charaia, Lashkhi 2022) and etc.

Despite the challenges in financing, potential sources for financing SME energy-efficient and solar energy projects include:

Traditional Bank Loans: This type of loan is currently one of the main sources of financing, although qualification criteria have been (Deloitte, 2016) and remain strict (World Bank, 2023).

Specialized Loan Products: Financial institutions increasingly offer loans tailored to energy-efficient and solar energy technologies for SMEs,

often providing flexible terms and lower interest rates to encourage investments in sustainable energy solutions. Innovative financial instruments, such as green bonds (EU, 2023; Azhgaliyeva & Kapsalyamova, 2023), can mobilize private capital for renewable energy projects for SMEs (World Bank, 2023).

Government grants and initiatives are crucial resources for financing SMEs:

Government funding through grants, tax incentives, and rebates is essential for supporting SME financing and may vary by region and program (DSIRE, 2024; IRENA, 2023). It can be asserted that targeted government incentives play a crucial role in overcoming financial barriers and stimulating SME investments in renewable energy projects (Wang & Zheng, 2018). Local governments and corporations also issue "green bonds," considering various tax exemptions (IMF, 2022).

Contemporary Financing Options for SMEs include:

- **Crowdfunding and Alternative Lending**: Online platforms play a significant role in alternative financing for SMEs, often with more lenient qualification requirements compared to traditional banks (Demirgüç-Kunt et al., 2022).
- **P2P Lending Platforms**: These platforms, focusing on sustainability, connect investors directly with borrowers (European Commission, 2024).
- **Community Development Financial Institutions (CDFIs):** CDFIs serve underprivileged community members, offering loans tailored to specific needs (CDFIs, 2024; Procredit Bank, 2022).

Additional Modern Options for Financing Energy-Efficient and Solar Energy Technologies:

- **Energy Performance Contracting (EPC):** This is an agreement between an SME and an Energy Service Company (ESCO) to finance and implement energy-efficient and solar technologies based on shared cost savings and guaranteed energy reductions (EU, 2020). For example, the Guaranteed Savings Model (EPC GS) involves ESCO assuming technical risks while the client secures a bank loan. This model is popular in countries such as the Czech Republic, Denmark, Canada, and Thailand (IEA, 2018).
- **Solar Power Purchase Agreements (PPA)**: SMEs can enter into solar power purchase agreements to avoid upfront costs by purchasing solar electricity through a long-term contract (Solar Energy Industry Association, 2018).
- **Green Leasing**: Lessors offer reduced lease payments or cover installation costs for energy-efficient technologies (US Green Building Council, 2024), providing an additional modern financing option for SMEs.

Thus, the literature review on the topic suggests that to improve access to financing for energy-efficient and solar energy technology projects for SMEs, it is advisable to:

- **Develop targeted financial products:** Tailor loan products and risk assessment criteria to SME-specific needs and risk types.
- **Simplify the application process:** Streamline application procedures and provide technical assistance to SMEs.
- **Raise awareness and build capacity**: Educate SMEs about available financing options.
- **Promote innovative financing models**: Encourage the use of crowdfunding, green bonds, and other innovative financial instruments.
- **Foster public-private partnerships**: Collaboration between governments, financial institutions, and other stakeholders can create broader and more effective support for SME financing in energy-efficient and solar energy projects.

Analysis of SME Financing for Energy-Efficient and Solar Technologies in Georgia - current financing landscape. To evaluate SME involvement in energy-efficient and solar technologies in Georgia, we need to assess investments from various financial sources:

International Financial Institutions (IFIs): Organizations such as the European Bank for Reconstruction and Development (EBRD), European Investment Bank (EIB), German KfW, and Austrian Development Bank (ADB) have established credit lines dedicated to environmental protection. These credit lines are utilized by local Georgian banks to fund energy-efficient and solar projects. The Green Growth Fund (GGF) and Global Climate Partnership Fund (GCPF) also play significant roles in this sector, with the Green Climate Fund (GCF) supporting EBRD's sustainable loans.

OECD and EU Projects: The OECD provides long-term financing through Georgian banks, while the EU4Environment project, funded by multiple international bodies, allocated approximately 20 million euros to support environmental projects from 2019 to 2022.

EBRD's Energy Credit Program: Supported by the Austrian Federal Ministry of Finance and GCF, the EBRD's Energy Credit program invested 54 million dollars in housing and SME projects, distributing over 42 million euros through commercial banks such as TBC Bank and Bank of Georgia.

Green Economy Financing Facility (GEFF): This facility provides loans between €300,000 and €1.5 million through banks like ProCredit Bank and TBC Bank. The EBRD remains a major investor, allocating 1.703 billion euros to green projects in Georgia between 2016 and 2021.

EIB and KfW Contributions: The EIB has committed 165 million euros for SMEs through Georgian banks and provides guarantees under the "EU Financing for Innovators" scheme. KfW supported hydropower projects with a 25 million euro loan. The Global Climate Partnership Fund focuses on green economy development, benefiting SMEs.

Green Loan Trends. In 2022, green loans in Georgia totaled 486 million lari ($180 million), marking a 16% increase from 2021. By the end of 2022, green loans constituted 3.2% of the total loan portfolio, up from 2.2% in 2020. TBC Bank led the market with a 45% share. However, high transaction

costs and a limited customer base restrict the growth of green loans.

Challenges and Government Initiatives. Georgia has committed to renewable energy through various agreements and introduced incentives like Feed-in Tariffs (FiTs), tax incentives, and low-interest loans. Despite these efforts, challenges remain, including regulatory gaps, limited financial resources, capacity-building needs, and market barriers.

To meet the research objectives, structured interviews were conducted with top managers from three major Georgian banks: JSC Bank of Georgia, JSC TBC Bank, and JSC ProCredit Bank. These banks are recognized leaders in financing energy-efficient and solar energy technologies.

Loan Financing Overview:

✓ **Bank of Georgia** financed 20 SMEs for solar energy projects by December 31, 2023, but did not provide loans for energy-efficient technologies.

✓ **TBC Bank** financed up to 10 SMEs for solar panel purchases, with 0.5 MW solar stations in operation and 1 MW stations expected in 2024.

✓ **ProCredit Bank** financed 50 SMEs for solar energy, issuing over 2,000 loans for energy efficiency since 2012.

Loan Conditions:

✓ **Bank of Georgia**: Loan conditions were standard, based on business needs, without specified details.

✓ **TBC Bank**: Operates on a "project finance" principle, covering 70% of project value with up to 18-year terms, requiring collateral.

✓ **ProCredit Bank**: Offers competitive rates, with terms dependent on factors like company strength, potentially offering 0% collateral for financially strong companies.

Loan Rejection Criteria: Common reasons across all banks: Insufficient collateral, inadequate credit history, difficulty in risk forecasting, poor business plans, and high risk.

Financing Sources: **Bank of Georgia** and **TBC Bank** use both bank resources and international credit lines. **ProCredit Bank** also utilizes these resources, with 90% of its portfolio consisting of SME loans.

Government Support and Alternative Financing: **Bank of Georgia** and **TBC Bank** highlighted government programs like "Produce Georgia" and subsidy initiatives. **ProCredit Bank** mentioned the importance of government support through interest rate subsidies and guarantee schemes.

Alternative Financing: **ProCredit Bank** offers leasing but does not currently offer other alternative financing options, such as P2P or B2B platforms.

Financial Education: All banks recognize that a low level of financial education in the high-tech sector impedes SME access to financing, stressing the need for greater public awareness.

In conclusion, Georgian banks are active in financing renewable energy technologies for SMEs, with ProCredit Bank leading in project financing. However, the banks' reliance on international financial institution resources and challenges such as collateral requirements and insufficient financial education pose obstacles to broader SME participation in renewable energy adoption.

The next target groups of the research include, on one hand, state agencies such as the Ministry of Economy and Sustainable Development of Georgia—specifically the Department of Energy Efficiency and Sustainable Development—and the Georgian National Energy and Water Supply Regulatory Commission (GNERC). On the other hand, the research also targets representatives from professional associations such as the Georgian Renewable Energy Development Association (GREDA), the Energy Community of Georgia, and international organizations such as WEG (World Experience for Georgia) and the Elizabet Eristavi - Energy Training Center.

Participants were sent a questionnaire via email, which consisted of five questions. The ages of the participants ranged from 28 to 55 years.

Question on What Could Increase Participation in Energy-Efficient and Renewable Energy Projects by SMEs in Georgia

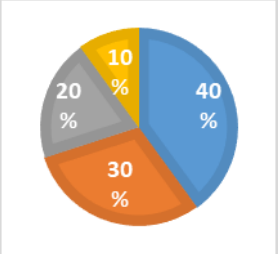

Diagram 1: Indicators for Increasing Participation in Energy-Efficient and Renewable Energy Projects by SMEs

Forty percent of respondents emphasized the need to raise awareness, particularly through more practical projects. Thirty percent identified the existence of additional enabling mechanisms, such as PPAs, feed-in tariffs, net metering, and origin certificates, as significant factors. Twenty percent mentioned the importance of reducing regulations and administrative barriers, as well as cutting subsidies on electricity. Finally, ten percent highlighted the need for proper regulation.

Question on What Main Enabling Measures Have Been Taken and What Is Planned to Promote Green Economy Development

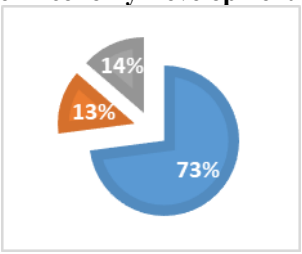

Diagram 2: Current and Future Directions for Promoting Green Economy Development

Seventy-three percent of respondents mentioned the power auctions announced by the Ministry of Economy (CFD). Thirteen percent highlighted the role of GNERC and the importance of net metering systems, while fourteen percent discussed the need for further improvement of the Energy Ministry's support in this area.

Question on Recommendations for Increasing SME Participation in Energy-Efficient and Renewable Energy Projects

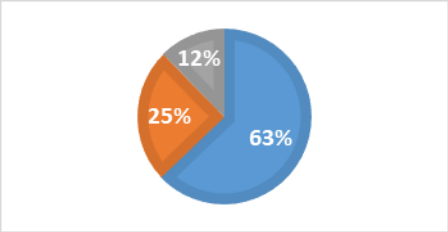

Diagram 3: Recommendations for Increasing SME Participation in Energy-Efficient and Renewable Energy Projects

Sixty-three percent of respondents advocate for increased awareness and more public projects. Twenty-five percent consider the establishment of appropriate regulatory and monitoring laws and agencies (such as energy efficiency laws, enforcement mechanisms for these laws, and support for ESCOs) as essential, while twelve percent suggest reducing electricity tariff subsidies.

Question on Measures Being Taken to Improve Access to Finance

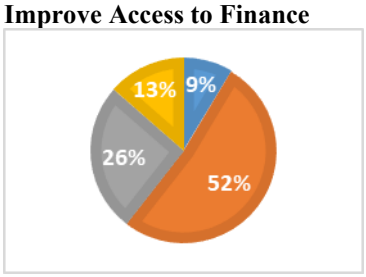

Diagram 4: Measures to Improve Access to Finance

Fifty-two percent of respondents mentioned the 'Produce in Georgia' project, twenty-six percent referred to the Ministry of Economy's energy auctions (CFD), thirteen percent mentioned the EBRD's enabling program, and nine percent believe that no sufficient measures are currently being taken.

Question on What Is Being Done to Support the Development of SME Skills and the Promotion of Entrepreneurial Culture

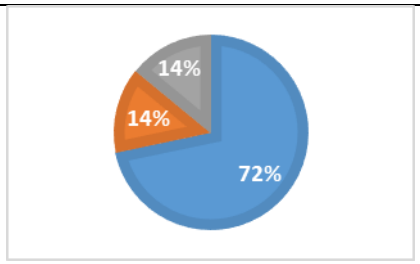

Diagram 5: Measures to Support the Development of SME Skills and Entrepreneurial Culture

Seventy-two percent of respondents consider various types of seminars and training, primarily conducted by the Ministry of Economy and Sustainable Development, to be appropriate. Fourteen percent mentioned donor organization projects, while fourteen percent did not answer this question.

The study also targeted companies using solar power systems, aiming to assess the profitability of these installations. Three companies that have been utilizing solar technology for over a year participated (see Table 1: Installed Capacity and Financial Indicators).

Aqua Geo LLC (Sno): This company installed a 664.6 kW solar system, costing $300,000, with support from Helios Energy Georgia and the "Produce in Georgia" program. The system, financed through a Bank of Georgia loan with a 10.9% interest rate (7% covered by the program), meets all the company's energy needs. The expected payback period is 3 years.

Golden Hands: A small enterprise that installed a 120.4 kW solar system, costing $65,000, with assistance from the "Produce in Georgia" program. The loan interest rate was reduced from 11% to 4%. The system eliminated the company's monthly electricity expenditure of 3,000 GEL. The company actively uses net metering to credit surplus electricity to other locations.

DG Consulting: This small enterprise installed a 108 kW solar system, costing $70,000, with funding from the "Agro Credit" program, allowing for a 2% loan interest rate. The expected payback period is 4 years. Besides financial savings, the system has prevented 121 tons of CO2 emissions within two years.

Table 1:

Installed Capacity and Financial Indicators

Station Name	Installed Capacity	Annual Generation	Total Investment	Payback Period
Golden Hands	102 kW	120,386 kWh	$65,000	4 years
Aqua Geo	665.6 kW	861,300 kWh	$300,000	4 years
DG Consulting	108 kW	140,400 kWh	$70,000	4 years

Recommendations and Findings:

Awareness: A significant challenge is the lack of information on energy-efficient technologies within the SME sector. Disseminating information about successful projects could encourage similar initiatives.

Donor Co-financing: SMEs currently using solar power systems recommend green technology transitions with donor support. Without co-financing, extended payback periods could deter investment.

State Support: While international co-financing programs are effective, additional state programs are necessary to bolster sector growth.

Barriers: In-depth interviews revealed barriers for SMEs in implementing solar energy, such as low awareness of net metering and skepticism about renewable energy.

Solar System Types: SMEs use three types of solar power technologies: Autonomous (OFF-GRID),

Grid-Tied (GRID-TIED), and Hybrid-Microgrid (MICRO GRID). Companies import solar components mainly from China or Europe, offering warranties ranging from 25 to 30 years for capacity and 5 to 10 years for products.

Net Metering: Awareness of net metering is low, causing doubts and hindering renewable energy adoption. Net metering allows excess solar energy to be fed into the grid, offsetting household energy needs when solar production is low.

Financing: Focus group participants identified financing sources like the "Preferential Agrocredit" state program, which offers loans with a 5% interest rate above the National Bank of Georgia's rate for amounts between 1.5 to 3 million GEL.

Conclusions

SMEs often prioritize cost reduction and short-term profitability over long-term investments and environmentally friendly technologies. However, investing in energy-efficient and renewable energy technologies can offer significant benefits.

Limited funding from Georgian commercial banks is partly due to the high risk associated with SMEs and a low level of awareness about energy efficiency and solar technology projects among both banks and SMEs.

Georgian banks prefer to finance large companies, which often receive preferential loans for energy-efficient and renewable energy technologies. SMEs face high interest rates and stringent collateral requirements, which were not detailed by surveyed bank employees. This is confirmed by SSI research.

Banks use their resources and targeted credit lines from international financial institutions to finance renewable energy projects, potentially offering additional benefits to clients.

Georgian banks play a significant role in supporting SMEs in adopting renewable energy technologies. However, the lack of detailed information about loan approval processes and solutions to challenges faced by borrowers is a study limitation. Addressing these challenges could reveal more potential for sustainable development and economic growth.

Despite using international financial resources for financing, Georgian banks show dissatisfaction with their reliance on external funds and often refrain from using their resources after these projects are completed.

SMEs primarily rely on their resources for funding energy-efficient and renewable energy technologies, due to limited information on funding opportunities from state and international institutions.

Although the Ministry of Economy and Sustainable Development has announced capacity auctions to support renewable energy with the CFD mechanism (contract for difference model), there is little interest among SMEs. This scheme mainly supports large-scale projects, with limited interest in financing SMEs.

The Ministry of Energy has received a few requests for funding energy-efficient and solar energy projects. This lack of demand is due to insufficient knowledge about the potential benefits and an overemphasis on perceived risks.

Low electricity consumption prices in Georgia limit the demand for energy-efficient and solar energy technologies, and thus the investment in these areas.

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MIGRATION, UNEMPLOYMENT AND ECONOMIC GROWTH: A REGIONAL PERSPECTIVE

Lia Bibilashvili
Professor
Gori State University, Georgia
Nino Orjonikidze
Professor
Gori State University, Georgia
DOI: 10.5281/zenodo.18923631

Abstract

The interplay between migration, regional economic growth and unemployment has emerged as a central concern in contemporary macroeconomic and legal discourse. While labor mobility is a primary driver of national and global prosperity, fueling innovation and industrial production, it frequently exerts significant pressure on regional labor ecosystems and public infrastructure. This tension creates a paradox where the drive for economic expansion may inadvertently threaten social stability and the fundamental right to an adequate standard of living for both host and migrant populations. This article explores how regional policy and international frameworks seek to reconcile the economic necessity of labor mobility with the requirement for localized labor market equilibrium.

Drawing on interdisciplinary perspectives from regional economics and international law, the study employs cost-benefit analysis (CBA) and sustainable development frameworks to examine the legal principles and economic tools required for an equitable transition in shifting labor markets. The objective of this research is to propose a normative framework wherein "sustainable regional development" is defined as the seamless integration of economic growth, labor market stability, and the protection of human dignity. By identifying mechanisms through which migration can be managed as a strategic asset rather than a disruptive force, the study emphasizes the need for a balanced approach. Ultimately, the article argues that managing these trade-offs through international cooperation and robust regulatory mechanisms is essential for fostering a regional development path that is resilient, equitable, and capable of sustaining long-term prosperity.

Keywords: Migration, Economic growth, Unemployment, Regional development, Sustainable development, Cost-benefit analysis, Labor markets, Human rights, Labor Mobility, Wage Suppression.

Introduction. In the discourse of regional economics, economic development and labor mobility are frequently presented as conflicting goals. On one hand, migration serves as a vital catalyst for prosperity, fostering employment, improving standards of living, and providing the human capital necessary to fuel technological innovation. On the other hand, unregulated shifts in labor supply can exert "negative externalities" on regional labor markets, manifesting as localized unemployment, wage suppression, and a debilitating strain on public infrastructure. These pressures can undermine the social fabric and the right to an adequate standard of living, creating a complex policy environment.

The central challenge for policymakers and scholars is to identify mechanisms through which economic interests can be pursued through migration without compromising the integrity of the regional labor ecosystem or human well-being. Human rights provide a crucial framework for this analysis; the protection of labor standards is not merely a policy preference but a matter of human dignity. Consequently, regional economic growth must be assessed not only through the lens of efficiency but also regarding its impact on the protection of the right to work and social security. This article examines the necessity of a comprehensive legal and economic framework to manage these trade-offs, ensuring that growth does not occur at the expense of regional stability.

Migration and Economic Growth: A Complex Relationship. Migration represents a significant economic interest, encompassing the movement of human capital that is essential for industrial production and regional dynamism. In many ways, human capital acts as the "natural resource" of the economic environment; its effective allocation is foundational to national prosperity. When managed strategically, the positive externalities of migration contribute to the resilience of host economies by addressing demographic gaps and fostering competition.

Drivers of Regional Prosperity

- Labor Supply Expansion: Mitigating demographic declines and providing the necessary workforce for high-growth industrial sectors.
- Skill Transfer and Innovation: The influx of diverse human capital and specialized knowledge that drives technological advancement and productivity.
- Increased Consumer Demand: The expansion of local market size and the stimulation of economic activity through increased consumption.

However, just as unregulated industrial activity can lead to the depletion of natural capital, unregulated labor shifts may generate externalities that compromise the stability of the regional economic environment.

The Unemployment Paradox: Negative Externalities in Labor Markets. The "pressure on

resources" often cited in sustainable development discourse is acutely felt within the regional labor ecosystem. Unregulated migration, while filling immediate industrial gaps, can lead to localized unemployment if the rate of labor influx outpaces the capacity of the regional economy to absorb and integrate new workers. In this context, the regional labor market functions like a delicate ecosystem; excessive, unregulated "harvesting" of job opportunities by a sudden influx can lead to a form of human capital depletion, where the local workforce is displaced and social protections are eroded.

Transboundary Labor Shifts Paralleling the concept of transboundary environmental harm, labor shifts often transcend national and regional borders, creating profound complexities in accountability. When economic migration is not aligned with regional development goals, it creates "transboundary externalities" such as the "brain drain" in sending regions and "labor gluts" in receiving ones. This necessitates a regulatory response that recognizes the interdependence of regional economies. Accountability for these shifts must be shared; just as a state is responsible for pollution that crosses borders, regional actors must be held accountable for the socioeconomic disruption caused by unregulated labor flows that ignore the "carrying capacity" of the host region's public services and job markets.

Economic Theory and Policy Tools: Cost-Benefit Analysis and Sustainable Development. Economic theory offers vital tools for understanding and mitigating the trade-offs between migration and employment stability.

Cost-Benefit Analysis (CBA) Policymakers can utilize CBA to evaluate the economic gains of labor mobility against the social and infrastructure costs. Drawing on the logic of Posner and Sunstein, this evaluative process includes:

1. Labor Market Absorption Capacity: Determining the regional economy's ability to integrate new workers without displacing the local workforce.
2. Infrastructure and Public Service Impact: Measuring the pressure on housing, healthcare, and educational systems.
3. Social Cohesion and Wage Stability: Evaluating the long-term impact on wage floors and social stability.

Furthermore, regional authorities can implement "behavioral nudges" to align migration with sustainable outcomes. By creating incentives - such as tax credits for hiring in under-served regional sectors or simplified visa pathways for "green" industries: policymakers can nudge labor mobility toward sectors that provide long-term regional stability rather than short-term exploitation.

Sustainable Development Sustainable development in this context is the integration of economic growth, labor market stability, and the protection of worker rights. It provides a framework for aligning industrial progress with human well-being.

Achieving Balance: Challenges and Strategies for Regional Stability. Achieving balance remains difficult due to short-term political pressures and insufficient regulatory mechanisms. States often prioritize immediate GDP growth over the long-term resilience of the labor market.

The application of ESG (Environmental, Social, and Governance) standards in hiring is particularly vital. By requiring multinational corporations to report on ethical recruitment and the impact of their hiring practices on local employment, regions can foster a corporate culture that prioritizes long-term social stability over the immediate cost-savings of wage suppression.

Conclusion. The intersection of migration, growth, and unemployment is a defining challenge for regional policy in the twenty-first century. While labor mobility remains essential for economic dynamism, it must not be pursued at the expense of the labor ecosystem or human dignity. Sustainable development requires a synergistic approach that integrates economic efficiency with labor market resilience and respect for international human rights.

By fostering international cooperation, strengthening regulatory frameworks, and adopting responsible economic practices, the international community can facilitate a development path that is equitable and resilient. The integration of human rights into labor and economic policies is not only a legal imperative but also a moral and practical necessity for ensuring the well-being of current and future generations.

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HISTORICAL SCIENCES

NATIONAL SELF-CONSCIOUSNESS IN 19TH CENTURY AZERBAIJANI ENLIGHTENMENT: IDEOLOGICAL SOURCES AND HISTORICAL TRANSFORMATION

Shabnam Babazade
Secondary School No. 2, Julfa District, Nakhchivan Autonomous Republic
https://orcid.org/0009-0007-7976-3404
DOI: 10.5281/zenodo.18923745

Abstract

This article analyzes the formation of the idea of national self-consciousness in nineteenth-century Azerbaijani Enlightenment within the context of ideological sources and historical transformation. The main objective of the study is to systematically examine the impact of the political, administrative, and social changes of that period on the formation of national identity, as well as to determine the role of Enlightenment ideology in constructing national identity. Particular attention is given to the influence of the new administrative model and social environment that emerged after the Treaty of Gulistan and the Treaty of Turkmenchay on the development of national consciousness.

The research employs historical-analytical and comparative-historical methods, comparing the period of the khanates with the stage of imperial administration in terms of national identity. In addition, a structural-functional approach is used to analyze the role of the education system, the press, and newly emerging social strata in the process of national self-consciousness. Through the method of source analysis, official documents of the period, statistical data, and the works of Enlightenment intellectuals were examined.

The findings of the study demonstrate that nineteenth-century Azerbaijani Enlightenment played a crucial role in reconstructing national identity on the basis of language, culture, and secular values, moving beyond a purely religious framework. The publication of *Akinchi* newspaper and the activities of Enlightenment figures such as Mirza Fatali Akhundzadeh and Hasan bey Zardabi contributed significantly to the formation of the ideological foundations of national consciousness. Thus, nineteenth-century Enlightenment can be regarded as a decisive stage of historical transformation in the transition of Azerbaijani national identity to its modern phase.

Keywords: nineteenth century, Azerbaijani Enlightenment, national self-consciousness, national identity, ideological transformation

Introduction

The division of Azerbaijani territories between Russia and Iran as a result of the Treaty of Gulistan and the Treaty of Turkmenchay in the early nineteenth century disrupted the political and geographical integrity of the country and had a profound impact on the process of national development. In particular, the incorporation of Northern Azerbaijan into the Russian Empire was accompanied by the introduction of new administrative mechanisms, policies of Russification, and the strengthening of imperial centralization. These policies aimed at weakening local governance traditions, placing religious and cultural institutions under control, and limiting the formation of a national elite.

Nevertheless, paradoxically, this very period can be characterized as a new stage in the development of Azerbaijani national thought. The political entities that had existed in previous centuries — the khanates and other feudal formations — were largely based on local, religious, and dynastic principles of legitimacy and did not produce a modern concept of national idea or national identity. However, the abolition of the khanates and the unification of Northern Azerbaijan within a single administrative system objectively led to the creation of a common economic space, a unified legal system, and a centralized administrative model. Although this system operated under the imperial framework, it was precisely within this structure that a common communication environment, the development of urban culture, and the establishment of new educational institutions laid the groundwork for the emergence of national consciousness.

Methods

The following scientific methods were employed in the article:

1. Historical-Analytical Method

A systematic analysis of the impact of nineteenth-century political events, treaties, and administrative changes on national consciousness.

2. Comparative-Historical Method

A comparison between the period of the khanates and the period of imperial administration in terms of national identity.

3. Structural-Functional Approach

An analysis of the functional role of administrative unity, the education system, and the press in the process of national self-consciousness.

4. Source Analysis Method

An examination of archival documents, official decrees, periodical press materials, and the works of Enlightenment intellectuals.

Literature Review

Studies on nineteenth-century Azerbaijani Enlightenment and the problem of national self-consciousness have been examined within various methodological approaches in national historiography. Existing research can be conditionally grouped into three main directions:

1. Political-historical context

2. The Enlightenment movement and intellectual activity

3. National identity and modernization theories

Within the first direction, both local and foreign scholars have extensively analyzed the political and geographical division of Azerbaijan following the Treaty of Gulistan and the Treaty of Turkmenchay in the early nineteenth century, as well as the socio-economic and administrative consequences of Northern Azerbaijan's incorporation into the Russian Empire (Mostashari, 2006; Altstadt, 1992; Kazemzadeh, 1951).

In the second direction, historians have primarily evaluated this period within the framework of colonial administration, administrative reforms, and social transformation (Azərbaycan tarixi, 1993; Həsənov, 2010; Mahmudov, 2014; Mustafayev, 2005; Quliyev, 2003; Rzayev, 2008).

The third direction encompasses conceptual studies conducted within the framework of national identity and modernization theories; however, research in this area remains relatively limited in Azerbaijani historiography.

The analysis of the existing literature demonstrates that although nineteenth-century Azerbaijani Enlightenment has largely been studied in the context of political and cultural awakening, the systematic examination of national self-consciousness as an ideological transformation remains relatively underdeveloped. Moreover, the indirect impact of imperial administration on the formation of national identity has often remained at a descriptive level. In this regard, the existing research gap necessitates a reconsideration of Enlightenment discourse from the perspective of national identity construction.

Thus, the present article aims to systematically analyze the formation of the idea of national self-consciousness in nineteenth-century Azerbaijani Enlightenment within the context of ideological and historical transformation, drawing both on the factual base of national historiography and on the conceptual approaches of modern theories of nationhood.

Discussion

The division of Azerbaijani territories along the Araz River following the Treaty of Gulistan (1813) and the Treaty of Turkmenchay (1828) in the early nineteenth century marked not only a political and geographical fragmentation but also the beginning of long-term demographic and social transformation. After Northern Azerbaijan was incorporated into the Russian Empire, the administrative system of the region was completely reorganized: the khanates were abolished, a commandant administration was introduced, and later a губерния (guberniya) and district (uyezd) system was established.

The newly established system initially faced significant difficulties in organizing effective local governance. Administrative challenges emerged, particularly due to the reluctance of local khans and beys to fully submit to imperial authority, which at times led to conflicts and unrest. In response, certain local khans, beys, and influential religious figures were granted ranks and privileges. These measures were primarily intended to secure their loyalty and bring them under imperial influence.

Tsarist Russia pursued a policy aimed at increasing the influence of the Russian language and promoted the opening of Russian-language schools. These schools were mainly attended by the children of wealthy and noble Muslim families.

Demographic Changes

Following the Treaty of Turkmenchay, the imperial government implemented a resettlement policy that led to significant changes in the ethnic composition of the region. Between 1828 and 1830, approximately 40,000–50,000 Armenian families were relocated from Iranian and Ottoman territories to the South Caucasus. A substantial portion of these settlers were directed to the regions of Iravan (Yerevan), Nakhchivan, and Karabakh.

According to the 1823 Russian fiscal census, the Muslim population (primarily Azerbaijanis) constituted the overwhelming majority in the Karabakh Khanate. However, official data from 1832 indicate an increase in the proportion of the Christian population in the region. By the end of the nineteenth century, particularly according to the 1897 All-Russian Census, the ethnic composition of the Baku Governorate had become considerably more diverse: Azerbaijanis (recorded at the time as "Tatars"), Russians, Armenians, and other ethnic groups lived together. According to the 1897 census, the population of the Baku Governorate exceeded 800,000, representing significant growth compared to the beginning of the century.

One of the main reasons for this growth was the development of the oil industry. From the 1870s onward, Baku experienced rapid industrial capitalist development. By 1901, Baku accounted for approximately 50 percent of the world's oil production. This economic dynamism led to an influx of labor from Russian, Armenian, and other ethnic communities into the region. As a result, urbanization accelerated, and Baku became one of the largest industrial centers in the Caucasus.

Socio-Structural Changes

As a result of administrative reforms, feudal relations gradually weakened. The administrative reforms of 1840 and 1846 established new judicial and administrative structures in Northern Azerbaijan. The municipal reform of 1870 strengthened elements of local self-government. These processes led to the emergence of new social strata, including an urban bourgeoisie, industrial entrepreneurs, and a secularly educated intelligentsia.

According to statistical data, by the end of the nineteenth century, the number of industrial workers in Baku was counted in the tens of thousands. In the early 1900s, more than half of Baku's population lived in an urban environment, which represented a high level of urbanization for the region. Urbanization significantly influenced the process of national identity formation, as Azerbaijanis from various regions entered into interaction within a unified urban space.

Impact on the Formation of National Consciousness

Demographic and social transformations directly influenced the discursive formation of national identity. Urbanization and the expansion of the education system led to the emergence of a new generation of intellectuals. The publication of the newspaper *Akinchi* in 1875 marked a turning point in the history of public thought. Issues of language, education, and national unity were systematically discussed in its pages.

Akinchi holds a distinctive place in the formation of national consciousness and laid the foundation for subsequent national press traditions. Through this newspaper, figures such as Hasan bey Zardabi, Said and Jalal Unsizade, Seyid Azim Shirvani, Sultan Majid Ganizade, Firudin bey Kocharli, Mirza Fatali Akhundzadeh, and others were able to convey important ideas to the public. On the pages of the newspaper, these intellectuals sought to shape young people's views on national issues and encouraged them toward education and science.

In general, the establishment of Akinchi in the late nineteenth century marked the beginning of both the Enlightenment movement and the process of national self-consciousness. Society encountered new ideas, and the foundations of a new national way of thinking were laid. Although due to publishing constraints the newspaper focused largely on agricultural topics, it nevertheless succeeded in encouraging a segment of society—particularly those inclined toward national thinking—to reflect on national problems and to express the concerns of the nation in the press.

The Enlightenment intellectuals who gathered around the newspaper also laid the foundation of national theater. With the initiative of Hasan bey Zardabi and Najaf bey Vazirov, modern Azerbaijani theater was established, further contributing to the popularization of national spirit and thought.

Literary scholar Alim Yashar Garayev wrote:

"Azerbaijanism is the philosophical and scientific expression of national self-consciousness and the revival of ethnic awareness. However, this idea and philosophy can transform from theory into practice, from national idea into national consciousness, only when not merely individual intellectuals but the masses demonstrate a sense of ownership of it in action and practice." (Omarov, V. (2012). Hasan bey Zardabi and Azerbaijanism. *Səs* newspaper, March 7).

Mirza Fatali Akhundzadeh's reformist ideas and his alphabet project laid the modern foundations of national cultural identity. During this period, the concept of the nation gradually moved beyond the framework of a purely religious community and transformed into an ethno-cultural and language-based form of consciousness. Akhundzadeh's struggle for the simplification and later reform of the alphabet was also aimed at advancing national consciousness. The prominent thinker believed that the complex script, burdened with numerous diacritical marks, constituted a serious obstacle to literacy for a population seeking education. Therefore, he devoted considerable effort to alphabet reform. His ideas played an important role in shaping national thought not only in Azerbaijan but also among Muslim peoples across a broader geographical space.

As literary scholar Yashar Garayev notes regarding Akhundzadeh, the founder of national dramaturgy, realist prose, democratic philosophical-aesthetic thought, and the first alphabet reform, "the rich and multifaceted creativity of M.F. Akhundzadeh transcends local national boundaries and acquires a general Eastern and universal historical significance across the Islamic world" (Garayev, 1985, p.).

Conclusion

The study demonstrates that nineteenth-century Azerbaijani Enlightenment constituted a decisive stage in the formation of national self-consciousness. Although the political changes that emerged following the Treaties of Gulistan and Turkmenchay initially appeared to limit national development, the new administrative system, urbanization, and expanding educational environment created conditions for the emergence of modern national consciousness.

In particular, the publication of Akinchi newspaper and the activities of Enlightenment figures such as Mirza Fatali Akhundzadeh and Hasan bey Zardabi contributed to the transformation of national identity from a religious framework to one grounded in language, culture, and secular values.

Thus, nineteenth-century Enlightenment can be evaluated as a stage of ideological and historical transformation in the development of Azerbaijani national identity.

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MATHEMATICAL SCIENCES

INTERACTION OF TWO HELICOIDAL VORTEX MODES AND THE CREATIONOF A THIRD "SPIRAL MOTION" AS A RESULT OF THE INTERACTION OF THESE TWO SINGLE-MODE VORTICES

Milyute E.
Milyus A.
IRG "LITAVEM-3"
Vilnius, Lithuania
DOI: 10.5281/zenodo.18923784

Abstract

In this paper, the interaction of a specific pair of "helicoidal" directions of single-mode vortices (for example, $k = (1, -2)$ and $\ell = (2,1)$), their characteristic $k \wedge \ell$, as the "strength of nonlinear coupling of modes" was studied, and it was investigated which new modes will appear in the case of specific sums of these values ($k + \ell, k - \ell$,etc.) for various forms of local interactions of these vortices, and a geometric picture was given of how, with a specific interaction of two single-mode vortices, a "third spiral" of a vortex with a new step/tilt with a certain intensity, having different characteristics, is born [2,4].

Keywords: vortex dynamics, topological methods in hydrodynamics, algebra of Lie, kern, interaction of vortices, twist, single-mode vortices.

1. Let the vortex field (or stream function) contain two "helicoidal" harmonics with wave vectors $k + \ell$ (these are two single-mode vortices in the Fourier basis). According to Arnold's geometric formulation [1] for 2D Euler on the torus T^2, the basis elements $e_k(x) = \exp(ik \cdot x), k \in \mathbb{Z}^2$ essentially form a Lie algebra of divergence-free fields, and their interaction is encoded by the structure constants of the commutator:

$$[e_k, e_\ell] = (k \wedge \ell)\, e_{k+\ell}\,. \qquad (1)$$

This leads to a fundamental fact: **two modes k and ℓ nonlinearly generate a third mode** with wave vector $k + \ell$. Geometrically, this means that two helical structures with different tilts (different directions of k and ℓ) create a third helical structure whose tilt corresponds to the sum of the wave vectors, i.e., the new direction $k + \ell$.

2. To get the full picture, let us take **a specific pair of helicoidal directions** and study the shape of the **third vortex spiral** that emerges.

Using formula (1), we calculate the oriented area of the parallelogram on vectors k and ℓ:

$$k \wedge \ell = k_1\ell_2 - k_2\ell_1, \qquad (2)$$

where **two modes give a third mode** $k + \ell$ with coefficient $k \wedge \ell$, which is equivalent to

$$|k \wedge \ell| = |k||\ell| \sin\varphi \quad (3)$$

where φ is the angle between k and ℓ.

From this we arrive at the definition:

- If the vortices are nearly parallel ($\varphi \approx 0$), then $\sin\varphi$ is small, which means we have $|k \wedge \ell|$, which implies that the interaction between single-mode vortices is weak;
- If the vortices are strongly "*crossed*" ($\varphi \approx \pi/2$), then $\sin\varphi \approx 1$, which implies that value $|k \wedge \ell|$ is large, which means we are dealing with a strong interaction between two "single-mode" vortices.

To understand the nature of the interaction between two "*single-mode*" vortices, we consider two cases where $k = (1, -2), \ell = (2, 1)$ (4). From conditions (4) it is shown, that these "*single-mode*" vortices are not parallel. Now we wind their "*interaction strength*" in algebraic form:

$$k \wedge \ell = 1 \cdot 1 - (-2) = 1 + 4 = 5 \neq 0\,, (5)$$

which proves the existence of a "*strong*" interaction between two vortices of the same mode (here the "*interaction*" coefficient is equal to 5).

3. Now we consider what new mode will emerge when this condition is met:

$$k + \ell = (1 + 2, -2 + 1) = (3, -1) \quad (6)$$

According to equation (1), we have:

$$[e_k, e_\ell] = 5\, e_{(3,-1)}. (7)$$

That is, the two original spirals generate a third, with a new direction (3, -1).

4. Therefore, having the result (7), we can geometrically describe the "third spiral" (as a helicoidal pitch).

Let's take the geometric quantities that interpret the torus:

$$x_1 = \theta\,, x_2 = z/L\,. (8)$$

And the mode phase

$$k \cdot x = m\theta + n\frac{z}{L}. \qquad (9)$$

The lines of constant phase (these are the natural "*helical*" lines/bands of the structure) have the form:

$$m\theta + n\frac{z}{L} = \text{const.} \tag{10}$$

If $\neq 0$, that

$$\boxed{z = -\frac{m}{n} L\,\theta + \text{const.}} \tag{11}$$

This is **a helix line** with a pitch of $a = -\left(\frac{m}{n}\right)L$ (in the sense $z = a\theta$).

For definiteness, let's take $L = 2\pi$. That we have:

a) **Helix 1**: $k = (1, -2)$

$z = -\frac{1}{-2}2\pi\theta = \pi\theta$. (12)

This is a "classic" screw connection $z = \pi\theta$.

b) **Helix 2**: $k = (2, 1)$

$z = -\frac{2}{1}2\pi\theta = -4\pi\theta$. (13)

This expression (13) describes a screw with **the opposite direction** and a steeper pitch.

c) **The resulting spiral** is given by the formula**:** $k + l = (3, -1)$

$z = -\frac{3}{-1}2\pi\theta = 6\pi\theta$. (14)

That is, a third helical structure emerges, **even steeper**, and of the same sign as the first.

5. Definition of the vortex channel intensity $\propto k \wedge \ell$:

We will call the left-hand side of equation (2) the **vortex channel intensity** and redefine the "intensity" level, depending on what we wish

(A) Intensity as the "strength of nonlinear mode coupling" (structure constant)

The most direct definition follows from the commutator – the modulus of the structure constant:

$$\boxed{\mathcal{I}_{k,\ell} := |k \wedge \ell|.} \tag{15}$$

Here, the expression (15) defines **the pure geometry** of the interaction of two vortex modes at a local location: which shows the extent to which two modes are capable of generating a new mode $k + \ell$.

Sometimes it is convenient to normalize equation (15) to obtain a number between 0 and 1:

$$\boxed{\hat{\mathcal{I}}_{k,\ell} := \frac{|k \wedge \ell|}{|k|\,|\ell|} = |\sin\varphi|.} \tag{16}$$

From this, we can conclude that the vortex intensity is zero when two single-mode vortices are parallel ($\hat{\mathcal{I}}_{k,\ell} \approx 0$), and the vortex intensity is unity when these two vortices are orthogonal ($\hat{\mathcal{I}}_{k,\ell} \approx 1$).

(B) Intensity as a "transmission coefficient" (energy channel for vortices).

If we need to calculate the "*transmission channel*" as it appears in formula (16) we find a characteristic formula for the coefficient, expressed in the following form:

$$\boxed{\mathcal{T}_{k,\ell} := \left|(k \wedge \ell)\,\frac{|k|^2}{|k+\ell|^2}\right|.} \tag{17}$$

Here, the factor $|k|^2/|k+\ell|^2$ takes into account the "*geometry*" of the $k + \ell$ directions and the mode scale (this already leads to an estimate of the exchange/transfer between modes).

6. Conclusion. Two helicoidal (single-mode vortices present in the vortex field) components with wave vectors k and ℓ. The nonlinearity of the Euler equations leads to the appearance of a mode with wave vector $+\ell$, since $[e_k, e_\ell] = (k \wedge \ell)\,e_{k+\ell}$. Thus, two helical structures with different tilts generate a third structure, the tilt of which is determined by the sum of the wave vectors. The strength (intensity) of this channel of the third vortex structure is proportional to $|k \wedge \ell|$, that is $|k \wedge \ell| = |k|\,|\ell|\,Sin\,\varphi$. Therefore, nearly parallel modes interact weakly, while substantially non-parallel (nearly orthogonal) modes make the maximum contribution [2-4].

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MEDICAL SCIENCES

THE BURDEN OF POSTOPERATIVE NOSOCOMIAL INFECTIONS: ANTIBIOTIC RESISTANCE, VIRAL DETERMINANTS, AND CLINICAL OUTCOMES

Mammadova Vugara
Head of the virology laboratory,
Scientific Research Institute of Medical
Prophylaxis named after V.Y.Akhundov, Baku,Azerbaijan
Ismayilova Sabina
Senior researcher,
Scientific Research Institute of Medical
Prophylaxis named after V.Y.Akhundov, Baku,Azerbaijan
Alazova Konul
Scientist,
Scientific Research Institute of Medical
Prophylaxis named after V.Y.Akhundov, Baku,Azerbaijan
Mirzayeva Arzu
Scientist,
Scientific Research Institute of
Medical Prophylaxis named after V.Y.Akhundov, Baku,Azerbaijan
DOI: 10.5281/zenodo.18923832

Abstract

Postoperative nosocomial infections remain a major challenge in modern surgical and intensive care practice, significantly affecting patient outcomes, healthcare costs, and mortality rates. The increasing prevalence of antibiotic-resistant pathogens and the contribution of viral determinants further complicate prevention and treatment strategies, particularly in trauma and critically ill patients.

Keywords: Postoperative nosocomial infections; surgical site infection; catheter-associated urinary tract infection; ventilator-associated pneumonia; bloodstream infection; antibiotic resistance; intensive care unit; clinical outcomes

Introduction

Surgical operations are one of the most important fields of modern medicine and play a vital role in the treatment of many diseases (1). Thanks to these operations, serious pathologies, including tumor diseases, traumas and infectious processes can be effectively eliminated. However, nosocomial infections in postoperative patients remain a serious clinical problem (2). Nosocomial infections, also called nosocomial infections, are infectious processes that occur in the surgical field or other organ systems in patients receiving hospital treatment. These infections cause worse surgical outcomes, longer patient recovery times, and additional financial burden (3). The most common nosocomial infections include surgical wound infections (SSI), catheter-associated urinary tract infections (CAUTI), ventilator-associated pneumonia (VAP), and bloodstream infections (BSI). These infections are mainly associated with microorganisms on the patient's own skin or from the environment. In recent years, the spread of antibiotic-resistant microorganisms makes the treatment of nosocomial infections even more difficult and poses serious challenges in clinical practice. Therefore, the development of new technological platforms and preventive measures to prevent nosocomial infections is extremely important (4).

Nosocomial infections can manifest themselves in different forms, and the most common types are as follows.

1. Surgical site infections (SSI):

It is the most common form of infection in the surgical field. These infections occur during or after surgery and delay the patient's recovery. SSIs may develop depending on the type of surgery, sterilization conditions, and the immune status of the patient (5).

2. Catheter-Associated Urinary Tract Infections (CAUTI): The risk of urinary tract infections increases in patients who use a urinary catheter for a long time. These infections are one of the most common infections in the hospital (6).

3. Ventilator-Associated Pneumonia (VAP): It is a form of pneumonia that develops in patients connected to a ventilator. VAP is a serious disease that increases the patient's risk of death (7).

4. Bloodstream Infections (Bloodstream Infections - BSI):

Infections from central venous catheters are characterized by the introduction of microorganisms into the bloodstream and can lead to septic conditions (8).

Infections are common complications of hospitalized patients, especially those with TBI (traumatic brain injury). Up to 50% of severe TBI patients admitted to intensive care units are reported to be affected by nosocomial infections. Hospital-acquired pneumonia and sepsis, in particular, are associated with increased mortality, longer hospital stays, increased ventilator use, increased risk of organ failure, and poorer functional outcome after TBI

compared with nosocomial infections that do not persist (9). The high incidence is multifactorial, primarily due to the need for mechanical ventilation, urinary catheters, and other invasive medical/surgical procedures that may introduce a source of infection. In addition, acute lymphopenia and the reported immunosuppression associated with a dysregulated T cell-mediated response after TBI may contribute to increased susceptibility to infections (10).

Surgical Site Infections (SSI): Surgical site infections (SSI) are infections occurring at the incision site within 30 days of surgery or within 1 year of implant involvement (11). Although SSI is recognized as a global problem regardless of surgical access, it is one of the most common healthcare-associated infections in low- and middle-income countries (LMIC) (12). SSIs in trauma patients are caused by factors such as severity of injury, general condition of the patient, and various procedural variables. High-dimensional injuries, including gunshot wounds, blast trauma, and severe accident injuries, significantly increase the risk of SSI due to extensive tissue damage, vascular destruction, and contamination. The risk of SSI can exceed 10% in patients with spinal trauma. Factors that further increase the risk include longer surgical time (greater than 3 hours), delayed surgery (greater than 72 hours after injury), large blood loss (greater than 600 mL), and fusion of more than three spinal levels. Posterior surgical approaches are more strongly associated with SSI than anterior approaches, possibly because of larger surgical fields and multiple exposures. In addition, prolonged use of urinary catheters (more than 5 days) and prolonged postoperative bed rest (more than 30 days) further increase the risk of SSI in these patients. Bacterial infections account for up to 70% of all infections in liver transplantation, followed by fungal and viral infections (13). Certain viruses, especially herpesviruses and polyomaviruses, interfere with host defenses and thus increase the risk of other infections. Viral infections are also considered as acute and chronic factors (14). Specific viruses such as EBV and HHV-8 can cause post-transplant lymphoproliferation or cervical cancer (papillomavirus). Other viruses such as influenza are mainly acquired through environmental transmission. All these conditions are easily detected in their early stages and can be effectively treated (15). The Centers for Disease Control and Prevention has recommended measures aimed at reducing the risk of SSI. These include; before surgery; optimal blood sugar control, smoking cessation, reduction of preoperative length of stay, intraoperative; strict asepsis, moderate use of antibiotics, effective hemostasis, removal of dead spaces, proper functioning of tissues, proper placement of drainage, after surgery; aseptic approach to wound care (16).

Catheter-Associated Urinary Tract Infections Tract Infections - CAUTI):

Catheter-related urinary tract infections are quite common. Among nosocomial urinary tract infections, 70–80% are related to the use of urinary catheters, and the risk of daily bacteriuria with catheterization is 3–10%. A Cochrane review of randomized controlled trials found that prophylactic antibiotics reduced the incidence of bacteriuria, pyuria, fever, and gram-negative isolates among surgical patients. However, there are concerns about the development of antibiotic-resistant urinary tract infections if antibiotic treatments are overused. Currently, there is no consensus regarding the use of prophylactic antibiotics in patients with short-term urinary catheters (17). CAUTIs are difficult to treat due to bacterial biofilm formation, which increases bacterial persistence and antibiotic resistance. Biofilm formation is based on the bacterial factor Fimbriae type 1 (FimA) and PapC, which are responsible for epithelial cell adhesion and pili adhesion to urinary tract cells or catheter materials, respectively (18). Catheter use for seven days resulted in biofilm formation in up to 50% of cases, and use for more than 28 days always resulted in biofilm formation (19). The main symptoms of UTI are dysuria, that is, discomfort and burning sensations in the urethra during urination, and an abnormal increase in its frequency. Other symptoms may include back pain, fever, cloudy, dark blood, or foul-smelling urine (20).

Ventilator-Associated Pneumonia (VAP**):** Hospital-acquired pneumonia (HAP) is defined as non-incubating pneumonia on admission occurring 48 hours or more after hospitalization. Ventilator-associated pneumonia (VAP) refers to pneumonia occurring 48 to 72 hours after endotracheal intubation (21). HAP is the second most common nosocomial infection in the United States (22). Urinary tract infections occur in 5-10 patients per 1000 hospitalized patients. Nosocomial pneumonia may develop in up to 6.8% of patients admitted to intensive care units (ICUs). Several pathogens, including a variety of bacteria, viruses, and fungi, have been reported to cause pneumonia in hospitalized patients (23). VIP occurs in 9–27% of all intubated patients in the intensive care unit, with approximately 90% of episodes of VIP occurring during mechanical ventilation (24).

Bloodstream Infections (Bloodstream Infections - BSI): Blood stream infections (BSI) are the third most commonly reported infection in intensive care units (ICU). Blood stream infection (BSI) is still a common infectious disease with high mortality worldwide (25). Sepsis or septic shock is among the most serious infections and is common in hospitalized patients requiring resuscitation, which can lead to prolonged hospital stays and high healthcare costs (26). According to relevant studies, patients with sepsis may have more than 50% chance of experiencing thrombocytopenia, and thrombocytopenia is strongly associated with poor prognosis and high mortality (27, 28). Patients with BSI often have invasive devices, mainly central venous catheters (73%) and urinary catheters (61.7%) (29). Platelets play an important role in pathophysiological processes, including hemostasis, thrombosis, inflammation, and antimicrobial host defense. It is believed that the occurrence of thrombocytopenia in patients with sepsis is mainly due to increased platelet loss and destruction as a

result of platelet activation stimulated by bacteria or their toxins (30).

Results

In our study, we found almost 23% of SSI in severe trauma patients undergoing surgery within 5 days of ICU admission, which was higher than standard SSI rates reported in recent years (31). Furthermore, we found that the majority of infections were caused by Gram-positive cocci, which have also been previously described in SSI (32). A total of 100 patients were included in the study, 64 of them were women (64%) and 36 were men (36%), the average age was 36.4 years. All of them were non-smokers, only 3 (3%), all men had diabetes. All were given intravenous antibiotics 1 hour before incision. 40 (40%) were elective procedures, and 60 (60%) patients underwent emergency surgery. Indications were mostly benign, 89 (89%), 7 (7%) malignant and 4 (4%) traumatic. The majority had ASA 1 and 11 in 85 (85%), operative approach was open midline in 51 (51%), open midline in 49 (49%). According to the degree of intraoperative contamination, 55 (55%) wounds were clean, 33 (33%) and 12 (12%) wounds were contaminated. The majority (54%) were general surgery (intestinal surgery) patients only (33). A review of catheter-related urinary tract infections was collected from 26 articles. Based on the information collected by country, the results were obtained for the United States (n = 5), England (n = 3), Turkey (n = 2), Sweden (n = 2), Brazil (n = 2), Saudi Arabia (n = 1), India (n = 1), Italy (n = 1) and Hong Kong. The most common reason for catheterization is spinal cord injuries (SCI). There were a total of 42,665 participants throughout the studies, with a gender breakdown of males (n = 4,176) and females (n = 3,647). The sex ratio was 1.15. Baseline analysis showed that the mean expected cost of using prophylactic antibiotics was $13.20, and the expected cost of not using prophylactic antibiotics and treating only a catheter-related urinary tract infection after diagnosis was $15.84. At the same time, using prophylactic antibiotics was higher than not. These results suggest that baseline prophylactic antibiotic use was a cost-saving strategy, while postoperative short-term indwelling urinary catheters were also available. From 1985 to 2022, 147 articles were published with an increasing trend year by year. Seventy-eight (53.1%) articles were published in the last 10 years. There were 109 case reports, including 130 patients with 141 stents and 1162 patients with 1182 stents, including 38 cases. The criteria for FUS length of stay have been defined as a period ranging from 3 to 12 months in previous studies. The age of included patients ranged from 2 to 92 years, with a mean age of 41.5 years. Children and adolescent patients accounted for 7.3%. The male to female ratio was 1.85. Primary reasons for stent placement in patients with FUS fall into 4 categories: In addition to stone treatment, the most common reason for stent placement (79.2%). During the 10-year study period, 2827 cases met our inclusion criteria, and their demographic, clinical, and microbiological characteristics are shown in Table 1. All-cause in-hospital mortality was higher in ICU patients (20.0%) than in non-ICU patients (9.8%). In-hospital all-cause mortality (20.7%) was significantly higher in patients with VIP than in non-VIP patients (8.8%).

One thousand four hundred and three patients were admitted to the trauma intensive care unit (TICU) during the study period; of these, 45 had ventilator-associated pneumonia (VAP). Mean age was 53.0 ± 22.5 years, median (IQR) for ISS was 14 (9–19). 948 (67.7%) of them were men, 1113 (79%) received blunt trauma. The mean ICU stay was 3.8 ± 6.0 days, and the mean hospital stay was 8.1 ± 8.3 days. 31 patients had massive transfusion (2.2%), acute kidney injury (AKI) was 1.2%, and 132 (9.4%) patients died. During the study period, we recorded 2353 admissions and hospitalizations. Among them, 223 (9.5%) developed ICU-BSI and were included in our study. The average number of ICU-BSI is 29 cases per year. The median age of our patients was 49 (IQR: 35–61), and 67.3% of them were male. One or more additional diseases were recorded in 57.8% of patients. The main reasons for admission were trauma (30.5%), coma (15.3%), acute respiratory failure (13.4%) and shock (13%). Data of 381 patients are presented. There was no difference in age or gender between the Gram-negative (GN)-BSI and Gram-positive (GP)-BSI groups. In the GN-BSI group, the primary source of infection was mainly urinary or biliary system (p = 0.011; p = 0.016; respectively) and in the GP-BSI group, it was related to the venous catheter (p = 0.103). The proportion of patients with diabetes was significantly higher in the GN-BSI group than in the GP-BSI group (p = 0.029), but the proportion of patients with kidney disease was lower (p = 0.003). In terms of categories of strains detected from blood cultures, Gram-negative bacteria were mainly Escherichia coli (98, 43%) and Klebsiella pneumoniae (50, 21.9%); Gram-positive bacteria were mainly Staphylococcus aureus (40, 26.1%) and Staphylococcus epidermidis (20, 13.1%).

Discussion

The results of this study confirm that postoperative nosocomial infections (SSI, CAUTI, VAP, and BSI) have a high prevalence in trauma and critically ill patients. The obtained findings coincide with previous international studies and reveal that nosocomial infections have a significant impact on clinical outcomes, especially in high-risk groups. First, the incidence of surgical site infections (SSI) of 23% is higher than reported in the existing literature. Tissue destruction, delayed surgical intervention, large incisions, and contamination of the surgical field may be associated with higher rates of SSI, particularly in severely traumatized patients. The clinical parameters obtained in our study - long surgical time, high number of emergency operations and hemodynamic instability of patients - coincide with the risk factors shown in previous studies. The predominance of gram-positive cocci is also consistent with the source, and the widespread occurrence of infections caused by Staphylococcus aureus in particular is expected. This raises the possibility that prophylactic antibiotics administered before surgery may not be sufficiently effective against the bacterial spectrum. In catheter-

associated urinary tract infections (CAUTI), biofilm formation and increased resistance of bacteria to antibiotics stand out as major factors complicating treatment. The observed 3–10% daily risk of bacteriuria and the near inevitability of biofilm with catheter use longer than 28 days support the clinical rationale of our results. Although there is a cost-benefit potential of prophylactic antibiotic use based on the available data, the widespread application of this strategy is still controversial due to the rise of antibiotic resistance. This study confirms that the epidemiology of CAUTI shows a similar trend in different countries and is especially higher in patients with spinal cord injury. Ventilator-associated pneumonia (VAP) and hospital-acquired pneumonia (HAP) in general are among the nosocomial infections with the highest mortality rates in critically ill patients. In our study, VAP was 40.7%, indicating that duration of mechanical ventilation plays an important role in intensive care patients. The high mortality rate obtained (20.7%) is consistent with the data reported in the literature and further proves that VAP leads to severe clinical consequences. As a result of the widespread and frequent use of antibiotics, the increase of resistant pathogens can be considered one of the causes of the observed complications. A higher proportion of gram-negative bacteria (especially E. coli and K. pneumoniae) in bloodstream infections (BSI) is consistent with modern trends. The predominance of Gram-positive bacteria, particularly Staphylococcus aureus, in venous catheter-related infections is consistent with patterns described in the literature. The widespread prevalence of thrombocytopenia in patients with BSI and its connection with high mortality rates are explained by biological mechanisms: activation of platelets during sepsis, increased consumption and disruption of immune processes lead to a severe clinical course in these patients. These mechanisms support the research results from a pathophysiological point of view.

The results of the study show that the occurrence of nosocomial infections in patients with severe trauma and critical condition is multifactorial and is closely related to the general condition of the patient, the number of invasive procedures, the length of stay in intensive care, the weakening of the immune system, and the microbiological characteristics of the hospital environment. These infections have a direct impact on increased length of hospital stay, higher treatment costs and increased mortality. Early diagnosis and modern technological methods, including new anti-biofilm materials, closed drainage systems and ventilator management protocols, can play a key role in preventing nosocomial infections.

Finally, this study suggests that a multidisciplinary approach to combating nosocomial infections involving the surgical team, intensive care physicians, infectious disease specialists, and microbiologists is necessary to improve patient outcomes.

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PEDAGOGICAL SCIENCES

A GOAL-ORIENTED APPROACH AND INTERDISCIPLINARY INTEGRATION IN THE TEACHING OF BIOLOGY

Novruzi Nurlana
Azerbaijan, Nakhchivan Autonomous Republic,
PhD in Biology Science,
Nakhchivan Teachers İnstitution, Head Teacher Position
ORCHID ID: 0000-0002-3712-2111
DOI: 10.5281/zenodo.18923878

Abstract

This paper argues that the teaching of Biology should not be limited solely to the transmission of scientific knowledge; it should also contribute to the development of students' life values and sense of responsibility. Students are expected to learn Biology not merely at the level of theoretical facts, but by understanding its relevance to real life. A goal-oriented approach in the instructional process enhances student motivation, fosters questioning and research skills, and promotes the formation of scientific thinking. To strengthen the spirit of inquiry, the importance of interactive teaching methods - such as brainstorming, problem-based learning, project-based learning, and classroom discussions - is emphasized. The article particularly highlights the role of integration in effective Biology instruction and explains three main directions of integration: intradisciplinary, interdisciplinary, and transdisciplinary. Intradisciplinary integration ensures logical coherence and continuity among topics within the subject; interdisciplinary integration connects biological knowledge with other scientific disciplines; and transdisciplinary integration supports the development of a comprehensive approach based on real-life problems.

Keywords: Biology; pedagogy; integration; intradisciplinary integration; interdisciplinary integration; transdisciplinary integration.

The teaching of Biology does not serve solely scientific purposes. Life-related issues must also be brought to the forefront and explained at a level that is understandable for students. While Biology is the science that studies living organisms, it is also a field that bears responsibility for their sustainability and continuity. For example, a student may acquire comprehensive information about plants. They can learn about the growth, development, reproduction, and death of any given plant. However, is this sufficient? Certainly not. Students must understand why they are learning this science. Only then can the teacher truly achieve the intended educational objectives. When students comprehend the purpose behind their learning, they begin to ask questions, conduct investigations, and develop a desire to learn more. In order to cultivate a spirit of inquiry among students, the use of interactive teaching methods is of great importance. Techniques such as brainstorming, problem-based learning, project-based learning, and discussion make Biology lessons more dynamic and meaningful. Once students understand the reason for their learning, they start asking questions, observing, comparing, and drawing conclusions. This process ultimately contributes to the development of scientific thinking.

Integration plays a crucial role in the effective teaching of Biology. In contemporary pedagogical literature and curriculum documents, it is emphasized that when integrating any subject, the following three essential stages should be taken into consideration:

1. **Content Integration Stage** – the alignment and connection of knowledge from different subjects and topics at the level of content.
2. **Methodological Integration Stage** – the harmonization of teaching methods, learning activities, and assessment criteria across disciplines.
3. **Integration of Outcomes and Skills Stage** – guiding students to apply the knowledge and skills they have acquired in various contexts and to solve interdisciplinary problems effectively.

The integration of subjects can be implemented in three main directions:

- **Intradisciplinary**
- **Interdisciplinary**
- **transdisciplinary** integration.

Intradisciplinary integration in teaching refers to establishing connections between topics within the same subject - linking previous, current, and subsequent topics in a coherent manner. For example, when teaching cell structure, connections should be made with tissues and organ systems. The teacher's primary responsibility is to maintain the continuity of the knowledge chain and ensure logical sequencing. Students should not perceive any topic as isolated or independent from others; instead, they should develop the ability to approach content as a unified and holistic system. In this process, the teacher's pedagogical competence, guidance, and supervision play a crucial role. Through this method, the teaching of topics not only reinforces logical progression and coherence in students' minds but also strengthens their understanding of the interrelated nature of concepts.

Intradisciplinary integration can be divided into two types according to content and orientation: **vertical integration** and **horizontal integration. Vertical integration** involves the alignment of standards across grade levels and is

sometimes referred to as cross-grade integration. For instance, when teaching the topic “Mechanism of Protein Biosynthesis” in Grade 10, connections can be established with the Grade 9 topic “Protein Biosynthesis.” This approach allows new knowledge to be introduced based on previously acquired concepts. **Horizontal integration**, on the other hand, refers to the interconnection of different content standards within the same topic. For example, while teaching protein biosynthesis in Grade 9, the teacher may refer back to previously covered topics such as the structure and function of ATP, DNA, and RNA, thereby reinforcing prior knowledge and establishing conceptual links [19].

Interdisciplinary integration represents the synthesis of common concepts, knowledge, and skills shared by several subjects, and involves the application of concepts and methods from one discipline to support the learning of another. The Biology curriculum in general education schools предусматрuеs not only intradisciplinary connections but also the broad implementation of interdisciplinary integration. The proper implementation of interdisciplinary connections offers several advantages. First and foremost, students understand the instructional material more easily. Lessons become more engaging and meaningful. Students’ scientific literacy and research skills are enhanced. This approach fosters multidisciplinary thinking and facilitates the practical application of knowledge. For example, Biology may be integrated with:

- **Chemistry** – in topics such as photosynthesis and biochemical processes;
- **Geography** – in the study of ecosystems and climate;
- **Mathematics** – in statistical analysis and graph construction;
- **Physics** – in energy exchange and related processes.

Transdisciplinary integration, at a higher level, encompasses a broader and more conceptual approach. Here, learning is organized around real-life problems. For instance, the topic of “Climate Change” can be analyzed within the contexts of Biology, Geography, Economics, and Social Sciences. This method promotes the development of analytical thinking, critical reasoning, and decision-making skills. Through transdisciplinary integration, the content learned at school is synthesized with knowledge and experiences acquired beyond the school environment.

Ultimately, the teaching of Biology is not merely the transmission of scientific facts; it is a process of understanding life itself. When students comprehend the purpose of the knowledge they acquire, they actively engage in the learning process. Intradisciplinary, interdisciplinary, and transdisciplinary integration enable Biology lessons to be organized in a more systematic, goal-oriented, and effective manner.

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PHILOLOGICAL SCIENCES

THE MANIFESTATION OF DOUBLE NEGATIONS AND MULTIPLE NEGATIONS IN THE SPOKEN ENGLISH OF IMMIGRANTS TO THE UNITED STATES

S. Mustafauly
Candidate of Philological Sciences
Department of Chinese Studies, Faculty of Oriental Studies
Al-Farabi Kazakh National University, Almaty
Abdurakhyn Nurkhalyk
PhD, Senior Lecturer
Department of Chinese Studies, Faculty of Oriental Studies
Al-Farabi Kazakh National University, Almaty
DOI: 10.5281/zenodo.18923914

Abstract
It is universally believed that people hold negative attitudes towards AAVE, which is thought to be wrong and corrupt the purity of Standard English. This paper is to discuss the unique pattern of double and multiple negations in AAVE.

Keywords: African American Vernacular English; double and multiple negations

1. Introduction

It was recognized a long time ago that black American spoke English differently from the whites. African American Vernacular English is a variety that has set phonological, morphological, syntactic, semantic, and lexical patterns. That is, it is a linguistic and distinct system that is not the same as classroom English, nor is it the same as other varieties of English although it shares features with them, of which double and multiple negation is a unique characteristic of AAVE. This paper is to discuss the unique pattern of double and multiple negations in AAVE.

2. The Unique Pattern of Double and Multiple Negations

This pattern is illustrated in the examples below and grouped in different ways:

(1) a. He can't never help us with our housework.
'He can't help us with our housework.'
b. David don't know nothing.
'David doesn't know anything.'
c. She ain't got none.
'She hasn't got any.'
e. I ain't never seen nobody preach under announcements,
'I have never seen anyone preach while they are giving announcements'
f. Bruce don't want no teacher telling him nothing about any no books.
'Bruce doesn't want any teacher telling him anything about any books.'
g. If you don't do nothing but farm work, your social security don't be nothing.
'If you only do farm work, then your social security isn't usually very much,'
h. Sometimes it didn't have no chalk, no books, no teacher.
'Sometimes there weren't any chalk, any books or any teacher.'

Once you have seen such kinds of sentences mentioned above, the thought of these ones are woeful corruption of English may at least cross your mind. The sentences in (1). (f. g. h.) stop at four, but there is no limit on the number of negators that can be used. A traditional prescriptive 'rule' in general American English states that double negatives are not grammatical because they make a positive. The formula multiplying two negatives yields a positive does not work for AAVE. The negative meaning of the sentences in （1） is not affected by the addition of negative elements, that is, they do not become positive. This system of negative marking contrasts with the system in mainstream English in that it allows more than one negative element in clauses that are interpreted as negative.

However, in complex sentences, situations are a little complicated. Look at the following examples:
(2). a. Wasn't no girls couldn't go with us.
'All the girls could go with us.'
b. Wasn't no girls could go with us.
'None of the girls could go with us.'
c. Don't nobody pay no attention to no nigguh that ain't crazy.
'If you are a crazy nigger, you will get attention.
d. Don't nobody pay no attention to no nigguh that's crazy.
'If you are a crazy nigger, you will not get attention.
e. It ain't nobody I can't trust.
'I can trust everyone.
f. It ain't nobody I can trust.
'I can trust no one.

In the complex sentences such as sentences in a, c, e, there are negators in both subordinates, so they are semantically positive. However, one of the subordinates in sentences in b, d, f is positive, so they become negative.

(3). a. Don't nobody want to go to the movies.
b. Do anybody want to go to the movies?

Negative inversion constructions are noted for their superficial resemblance to yes-no questions in that that the auxiliary precedes the subject. Compare

the sentences in （3）, noting the similarities and differences between the negative inversion constructions (3a) and the yes-no question (3b). Both of the sentences are grammatical in AAVE. The major difference between the sentences is that (3a) is not a question; it makes an assertion, but (3b) asks a question. This distinction is reflected in the intonation of the sentences. The sentence in (3a) is uttered with declarative intonation, and (3b) has question intonation.

3. Some implications

AAVE is rule-governed and it has a systematic form of communication and has practical application, but they are not always successful in combating negative attitudes towards the linguistic system. Why do people think the English which black people speak was felt to be debased or corrupt? It was also considered to be the result of –and indeed proof –of the inherent inferiority of black people. Black, it was thought, could not speak English properly since they were not capable of it. This view obviously has absolutely no basis in fact. The subject as a whole is in any case fraught with various social and political implications. Language as a powerful commodity that can be exploited by those in power, as well as those who are not, to exclude some and include some.

So statusful are Standard English and prestige accents that they are widely considered to be ‘correct’, ‘beautiful’, ‘nice’, ‘pure’ and so on. Other nonstandard, non-prestige varieties are often held to be ‘wrong’, ‘ugly’, ‘corrupt’ or ‘lazy’. Standard English, more over, is frequently considered to be the English language, which inevitably leads to the view that other varieties of English are some kind of deviation from a norm, the deviation being due to laziness, ignorance or lack of intelligence.

4. Conclusion

Linguistically speaking, all languages are equally good as linguistic systems. There is no such thing as a pure language. All languages are subject to change, and they are all the product of influence and admixture from other languages. In each case, linguistic inequality can been seen as a cause (along with many other factor, of course) of social inequality, but also as a sequence of it.

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PHYSICAL SCIENCES

INFLUENCE OF RADIATION DEFECTS ON PBTE SEMICONDUCTOR FILMS IMPLANTED WITH (AR+) IONS

H.C. Kasamanli
associate Professor
ORCID: 0009-0006-4860-4956
K.M. Suleymanov
associate Professor
ORCID: 0009 0001 7140 3371
N.G.Askerli
Assistant
R.I.Asgerova
doctoral student
Azerbaijan Technological University
ORCID: 0009 0007 9551 1899
DOI: 10.5281/zenodo.18924882

ВЛИЯНИЕ РАДИАЦИОННЫХ ДЕФЕКТОВ НА ПОЛУПРОВОДНИКОВЫХ ПЛЕНОК PbTe ИМПЛАНТИРОВАННЫХ ИОНАМИ (Ar^+)

Касаманли Гамлет Джумшидович
доцент
ORCID: 0009-0006-4860-4956
Сулейманов Камиль Мурсалович
доцент
ORCID: 0009 0001 7140 3371
Аскерли Наджийе Галибовна
ассистент
Аскерова Рада Исфандияровна
докторант
Азербайджанский Технологический Университет
ORCID: 0009 0007 9551 1899

Abstract

Semiconductor PbTe films were obtained by discrete evaporation and were block single crystals oriented with the "///" axis perpendicular to the layer plane. During ion bombardment of PbTe with Ar+ ions, the energy of atoms was E=90 keV, the current density during implantation γ=0.5…..1 μA/cm^2, the integral dose of irradiation varied from 10 μC/cm^2 (6.2·10^{13} cm^{-2}) up to 900 μC/cm^2 (5.6·10^{15} cm^{-2}). In terms of the volume unit of the PbTe film, the concentration of implanted <N_{Ar}> atoms ranged from 1.3·10^{18}cm^{-3} to 1.5·10^{20}cm^{-3}.The main result of bombardment with argon ions is a change in the type of conductivity (the sign of the Hall coefficients R and thermopower α) from hole to electron.

Аннотация

По типу PbTe (d≃0,35....0,55мкм) химической связи эти материалы относятся к полярным полупроводникам, связь смешанная ионно – ковалентно – металлическяв. Рентгеноструктурные исследования показали, что конденсаты представляют собой мозаичные монокристаллы, ориентированные осью <///> перпендикулярно плоскости подложки. Энергия имплантируемых ионов Ar^+ составляла E=90кэВ, плотность тока при имплантации j=0,5…1мкА/ ⟦см⟧ ^2, интегральная доза облучения изменялась от 10 мкКл /см^2 (6,2 • 10^{13}см$^{-2}$) до 900 мкКл/см^2 (5,6 • 10^{15}см$^{-2}$). В пересчете на единицу объема пленки PbTe концентрация имплантированных атомов <NA_r > составляла от 1,3•10^{18}см$^{-3}$ до 1,5•10^{20} см$^{-3}$. Основной результат бомбардировки ионами аргона-смена типа проводимости (знака коэффициентов Холла R и термо эдс α) (1) с дырочного на электронный. (рис.1). Один из образцов который до имплантации имел проводимость п – типа, сохранил знак R и α.

Keywords: spread of points, implantation, annealing, radiation defects, polar semiconductor

Ключевые слова: разброс точек, имплантация, отжиг, радиационные дефекты, полярный полупроводник

Халькогениды свица имеют кубическую решетку типа NaCl. Элементарная ячейка гранецентрирования. Постоянная решетки при переходе от селена до теллурида свинца изменятся монотонно прмерно на 10% и равно 0,612 нм; 0,65нм для PbSe и PbTe соответственно.

Тонкие слои PbTe (d≅0,35....0,55мкм) на слюде были изготовлены базовой технологии. Рентгеноструктурные исследования показали, что конденсаты представляют собой мозаичные монокристаллы, ориентированные осью </// перпендикулярно плоскости подложки. Свеженапыленные слои обладали проводимостью как *n* – так и *P* – типа. Следует указать, что их свойства изменялись во времени. Отжиг слоев при T = 580….600K в течение 30 мин. в атмосфере гелия стабилизировал свойства образцов. После отжига пленки в подавляющем большинство приобретали проводимость *P* – типа. Изготовление пленок производилось в установке вакуум на уровне (2….3)· 10^{-6} мм *рт. ст.*

Таким образом, преобладающий тип радиационных дефектов имеет донорный характер. Баланс воздействия дефектов по Френкелью в подрешетках свинца и халькогена с учетом зарядового состояния межузельных атомов Pb и Te и вакансий таков, что совокупность $[V_{Te}]$ + $[V_{Pb}]$ + $[J_{Te}]$ + $[J_{Pb}]$ должна поставлять один электрон.

При этом, однако, сразу возникает вопрос о дозовой зависимости концентрации электронов после имплантации. Казалось бы, поскольку с ростом дозы увеличивается концентрация радиационных дефектов, должна увеличиваться и концентрация электронов. Из рис.1 видно, что эта не так. Зависимость *n* (Д) практически отсутствует. После имплантации холловская концентрация составляет (0,7….1,5) · 10^{18} $см^{-3}$ [1].

Ионной имплантации при Д = 100мкКл/$см^2$ (6,2 · 10^{14} $см^{-2}$) было подвергнуто около десятка образцов. До имплантации они обладали различными холловскими концентрациями дырок p = (0,15….2,2) · 10^{18} $см^{-3}$, а один из образцов имел проводимость n – типа с n = 4 · $10^{17}$$см^{-3}$. После имплантации разброс значений *n* составил всего (0,7….1,1) · 10^{18} $см^{-3}$, *т.е.* практически отсутствовал. Таким образом, отсутствует зависимость концентрации носителей после имплантации от исходной концентрации носителей.

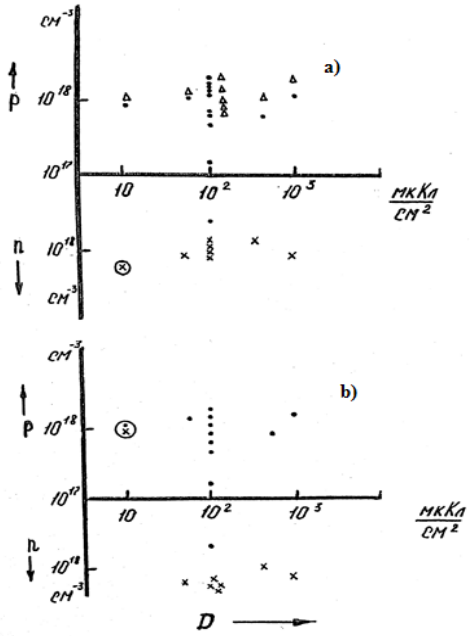

Рис. 1. Влияние ионной бомбардировки и отжига на холловскую концентрацию носителей. Температура измерений: а) T = 300K; б) T = 77K.

• - до имплантации; x – после имплантации; Δ - имплантированные образцы после отжига

Исключение составляет один образец, подвергнутый имплантации при наименьшей дозе (10мКл/$см^2$). Данные для него помечены на рис.1 кружками. Видно, что коэффициент Холла для него отрицателен при T = 300K и положителен при 77K. Коэффициент термоэдс при 300K положителен, что не соответствует знаку R и очень мал по величине: $\alpha_{300} = +20$мэВ/к при $R_{300} = -4см^2Кл$, вместе $\alpha = -270$мэВ/к. Значение Q для этого образца в 3,5 раза превосходит средние данные для других образцов *n* – типа, причем Q > 0. Здесь налицо ярко выраженная слоистая неоднородность, причем в образца после имплантация имеются слои с разным типом проводимости.

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PSYCHOLOGICAL SCIENCES

AIR POLLUTION AND ACCELERATED COGNITIVE DECLINE: IMPLICATIONS FOR ALZHEIMER'S DISEASE PROGRESSION A SYSTEMATIC REVIEW (2020–2025)

AmirHossein Montazeri Ghahjavarestani
Universitat Autònoma de Barcelona, Barcelona, Spain
Hanieh Rafiei
Yazd Shahid Sadoughi University of Medical Sciences, Yazd, Iran
DOI: 10.5281/zenodo.18924851

Abstract

Background: Fine particulate matter ($PM_{2.5}$) is now recognized as one of the most harmful urban environmental exposures for brain health.

Objective: This systematic review synthesizes evidence from 2020–2025 linking long-term $PM_{2.5}$ exposure to accelerated cognitive decline and Alzheimer's disease (AD) progression.

Methods: PRISMA 2020-compliant search of PubMed, Scopus, Web of Science, and Embase (Jan 2020–Oct 2025). Included studies quantified $PM_{2.5}$ exposure and reported AD-related outcomes (cognition, biomarkers, imaging, and pathology). Quality was assessed using the Newcastle-Ottawa Scale and SYRCLE tool.

Results: Twenty-eight studies (17 human cohorts, 11 preclinical) were included. A 10 μg/m³ increase in $PM_{2.5}$ was associated with 12–34% higher dementia incidence [1-4] and faster Aβ/tau accumulation [5-8]. Key mechanisms comprised olfactory translocation, blood- brain barrier disruption, oxidative stress, and chronic neuroinflammation [9-14]. Effects were amplified in APOE ε4 carriers [15, 16].

Conclusion: $PM_{2.5}$ is a potent, modifiable accelerator of sporadic AD. Urgent air-quality policies and personal protection strategies are needed.

Keywords: air pollution, $PM_{2.5}$, cognitive decline, Alzheimer's disease, neuroinflammation, amyloid-β, tau pathology

1. Introduction

Alzheimer's disease (AD) is the leading cause of dementia worldwide, with prevalence projected to triple by 2050 [17]. Although genetic factors such as APOE ε4 play a role, environmental exposures drive the majority of sporadic cases [18]. Among these, fine particulate matter ≤2.5 μm ($PM_{2.5}$) has emerged as a major modifiable risk factor, particularly in urban populations, through chronic low-grade brain inflammation and accelerated neurodegeneration [1, 19]. This systematic review examines evidence

published between 2020 and 2025 on the mechanisms and magnitude by which $PM_{2.5}$ hastens cognitive decline and AD progression.

2. Methods

The review followed PRISMA 2020 guidelines [20]. The full search strategy,

inclusion/exclusion criteria, and risk-of-bias assessments are provided in Supplementary File 1. In brief, 1,523 records were screened; 28 studies met criteria (17 human, 11 preclinical).

3. Mechanisms of $PM_{2.5}$ Neurotoxicity

3.1 Olfactory translocation

Ultrafine particles reach the brain directly via the olfactory bulb, bypassing the blood-brain barrier (BBB) [9, 10]. Autopsy and rodent studies confirm $PM_{2.5}$ nanoparticles within hippocampal neurons and microglia [11].

3.2 Blood-brain barrier compromise

$PM_{2.5}$-induced peripheral cytokines (IL-6, TNF-α) disrupt tight-junction proteins, increasing BBB permeability and allowing inflammatory mediators into the CNS [12,13].

3.3 Oxidative stress and mitochondrial dysfunction

Transition metals and polycyclic aromatic hydrocarbons adsorbed onto $PM_{2.5}$ generate reactive oxygen species, impairing mitochondrial function and triggering neuronal apoptosis [14, 21].

4. Interaction with AD Hallmarks

4.1 Amyloid-β pathology

Chronic $PM_{2.5}$ exposure upregulates β- and γ-secretases while impairing microglial phagocytosis, resulting in accelerated Aβ plaque deposition [5, 6, 22].

4.2 Tau hyperphosphorylation

Activation of JNK and p38 MAPK pathways by $PM_{2.5}$ promotes tau detachment from microtubules and neurofibrillary tangle formation [7, 8].

4.3 Neuroinflammation

Sustained microglial priming and astrocyte reactivity create a self-perpetuating inflammatory milieu that amplifies both Aβ and tau pathologies [23, 24].

Pathway	Primary Insult	Molecular Event	AD Consequence	Representative Studies
Olfactory Translocation	Direct neuronal uptake	Nanoparticle accumulation	Early Aβ seeding	[9, 10, 11]
BBB Disruption	Cytokine-mediated tight-junction loss	Increased permeability	Inflammatory influx	[12, 13]
Oxidative Stress	generation	Mitochondrial failure	Neuronal apoptosis	[14, 21]
Neuroinflammation	Microglial priming	Chronic IL-1β / TNF-α release	Aβ C tau acceleration	[23, 24]
Gene–Environment	APOE ε4 interaction	Enhanced uptake and inflammation	Amplified risk	[15, 16]

5. Epidemiological Evidence

Meta-analyses and large cohorts consistently report dose-dependent associations. A long-term increase of 10 μg/m³ in $PM_{2.5}$ concentration is associated with a 12–34% rise in dementia incidence [1-4] and a faster rate of global cognitive decline [25,26].

Neuroimaging studies demonstrate reduced hippocampal volume and cortical thickness mirroring early AD patterns [27, 28].

6. Conclusion

Chronic exposure to $PM_{2.5}$ accelerates Alzheimer's disease pathogenesis through multiple converging pathways. Reducing ambient $PM_{2.5}$ represents one of the most powerful population-level strategies to lower the global burden of dementia [18].

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SOCIAL SCIENCIES

OPPORTUNITIES AND TRENDS IN THE USE OF AI AGENTS IN TOURISM

Makasarashvili Tamar
PhD in Economics, Professor, Gori State University, Georgia
Giguashvili Giuli
PhD in Economics, Professor, Gori State University, Georgia
DOI: 10.5281/zenodo.18924957

Abstract

In the development of modern digital technologies, artificial intelligence systems and agents hold a special place. AI agents represent one of the leading directions of contemporary technological progress, as they are capable of making autonomous decisions and performing tasks automatically. Through their application, it is possible to create smarter systems and utilize them in various ways.

In the tourism industry, the use of AI agents offers significant opportunities in travel planning personalization, automation of customer service, optimization of operational processes, and enhancement of security. Particularly important is the impact of AI agents on improving customer experience, enabling data-driven decision-making, and advancing the concept of smart tourism. The integration of AI agents presents substantial opportunities for enhancing the quality and efficiency of tourism services; however, it also raises challenges related to data privacy, ethics, and technological dependency.

The paper discusses the opportunities for applying artificial intelligence in tourism, the significance and role of AI agents in the development of tourism businesses, and analyzes current trends, including the integration of generative AI, the expansion of autonomous booking systems, and the adoption of sustainability-oriented solutions. The research findings suggest that AI agents present considerable opportunities for enhancing the quality and efficiency of tourism services, while also posing challenges in terms of data privacy, ethics, and technological dependence.

Keywords: Artificial Intelligence, AI Agents, Future Technologies.

In the era of digital transformation, artificial intelligence plays a significant role in society, science, the economy, and business, and is used in both the public and private sectors. The tourism industry is one of the fields where artificial intelligence (AI) technologies are being implemented most actively. In recent years, particular attention has been drawn to AI agents - autonomous software systems that perform complex tasks through data analysis and decision-making with minimal human intervention. [1]

The AI agent systems market is growing rapidly: according to forecasts, its volume will increase from USD 5.2 billion in 2024 to USD 227 billion by 2034, representing an approximate annual growth rate of 45%. [2]

This trend is directly reflected in tourism, where personalized services, real-time communication, and data-driven decision-making are critically important. The potential of AI agents in tourism can be considered in several key areas. The first is travel planning and personalization, where AI agents enable the selection of individualized itineraries, provisioning tailored recommendations, and organizing bookings based on users' personal data. Additionally, AI agents provide personalized information before, during, and after travel, including through text and voice communication. [3]

Research shows that the use of multi-agent AI models ensures a greater diversity of tourism offerings, making it possible to discover less popular destinations while reducing demand for overcrowded tourist areas. In practice, such technologies are already in use: AI-based tools create detailed itineraries within minutes and integrate flight, accommodation, and activity bookings into a single platform. For example, the Australian travel media brand Escape launched an artificial intelligence assistant, "Ask Skye," to address vacation planning challenges. It is designed to simplify planning and deliver detailed itineraries in minutes (sometimes seconds), which can be downloaded and shared with friends, family members, or a personal travel agent. [4]

Another major area of the tourism sector where AI is already widely implemented is customer service and communication. AI chatbots and voice assistants operate 24/7, responding to customer inquiries in multiple languages. AI agents are also functioning in areas such as operational efficiency and business process automation, where they assist companies in automatic email processing, simplifying booking procedures, and data analysis. That reduces costs and increases customer satisfaction. [5]

Particular importance is attached to secure knowledge-based chatbots that provide personalized real-time assistance while simultaneously protecting data and systems from cyberattacks. A wide range of AI systems, including intelligent search engines, translation tools, and robots, are already being utilized in the tourism and hospitality sectors to enhance service quality. [6]

In the context of implementing the latest digital technologies in tourism, smart tourism and security are especially significant areas. [7] The use of AI agents in these fields includes monitoring visitor flows, ensuring safety, and managing infrastructure. Through AI-powered cameras, it becomes possible to

control tourist sites in real-time, assess crowd density, and manage emergencies effectively. [8]

In the field of interactive experiences and virtual tours, multimodal AI agents already provide capabilities for visual environment perception and map interpretation, assisting tourists in better understanding locations and receiving recommendations. AI-based virtual tour applications deliver multilingual information about cultural heritage, enhancing the quality of the tourist experience. One example in this direction is an artificial intelligence-based application developed by a group of students at Dr. A.P.J. Abdul Kalam Technical University (AKTU) in Lucknow, India, designed to facilitate navigation in Lucknow and offer virtual tours of the city's legendary Imambara complex. [9]

Among the contemporary trends in the use of AI agents in the tourism sector, the following should be highlighted:

- Growth of agent-based systems — the rapid expansion of the AI agents market indicates prospects for their widespread implementation across various industries, including tourism.
- Digitalization of travel planning — research shows that a significant proportion of young people already use AI tools to plan their vacations.
- Autonomous booking systems — companies are preparing for a reality in which AI agents will independently perform booking operations on behalf of customers.
- Research growth in generative AI — academic and industry research in tourism and hospitality is showing increasing interest in generative AI and data analytics.
- Sustainability focus — AI-based recommendations contribute to the sustainable development of tourism, although theoretical and practical frameworks in this area are still in the process of formation. [10]

Conclusion. Thus, the integration of AI agents into the tourism industry creates new opportunities - from personalized services to enhanced operational efficiency and improved security. Since AI agents represent one of the leading directions of modern technological progress, it is expected that they will become an integral part of the tourism experience, not only planning trips but also independently performing booking and communication functions in the future. In the future, AI agents will become a significant component of the digital tourism ecosystem, which requires their responsible and strategic implementation. At the same time, it is essential to consider ethical, security, and sustainability considerations.

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TECHNICAL SCIENCES

DEVELOPMENT OF LIGHTWEIGHT ENERGY-EFFICIENT CONSTRUCTION BLOCKS INCORPORATING RECYCLED PLASTIC AND ALTERNATIVE MATERIALS

Merab Baratashvili
Tornike Baratashvili
Akaki Tsereteli State University, Kutaisi, Georgia
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Abstract

This study presents the development and performance evaluation of lightweight energy-efficient construction blocks produced using recycled plastics and alternative mineral materials. The primary objective is to significantly reduce cement consumption and associated CO_2 emissions while maintaining adequate compressive strength and enhanced thermal insulation in accordance with European standards. The blocks were manufactured using river sand, crushed brick, basalt aggregate, volcanic ash, and shredded secondary plastics. Experimental results demonstrate that the developed blocks achieve a density of 500–650 kg/m³, compressive strength of 2.2–3.0 MPa, and thermal conductivity below 0.4 W/m·K. The findings confirm the feasibility of producing structurally reliable, thermally efficient, and environmentally sustainable masonry units with reduced cement content.

Keywords: lightweight blocks; recycled plastic; energy efficiency; cement reduction; thermal insulation; sustainable construction

1. Introduction

Cement-based construction materials are among the largest contributors to global CO_2 emissions, primarily due to the energy-intensive clinker production process. On average, the manufacture of one ton of Portland cement releases approximately 0.8–0.9 tons of CO_2. Consequently, reducing cement consumption without compromising mechanical performance has become a critical challenge in sustainable construction.

Recycled plastics offer considerable potential for lightweight building materials due to their low density and thermal conductivity. When combined with secondary mineral aggregates such as crushed brick, volcanic ash, and basalt, plastics can contribute to the formation of composite masonry units with reduced density, improved insulation properties, and sufficient compressive strength for non-load-bearing and low-rise applications.

This study focuses on the systematic development of cement-reduced construction blocks incorporating recycled plastics and alternative aggregates, with experimental assessment of their physical, mechanical, and thermal properties.

2. Materials and Methods

2.1 Raw Materials

The following materials were used:

Cement: Ordinary Portland Cement (OPC), reduced content (10–15 wt.%)

Aggregates: River sand, crushed brick, and basalt aggregate

Volcanic Ash: Natural pozzolanic additive to enhance microstructure and binder efficiency

Recycled Plastics: Shredded secondary plastics, density 150–250 kg/m³, non-toxic and chemically inert

2.2 Block Composition

The mix design was optimized to achieve the following target properties:

Density: 500–650 kg/m³

Thermal conductivity: < 0.4 W/m·K

Compressive strength: 2.2–3.0 MPa

The reduced cement content functions primarily as a structural binder, ensuring stress transfer between mineral aggregates and plastic inclusions rather than acting as a dominant load-bearing phase.

2.3 Experimental Methods

Blocks were cast in standardized molds and cured for 28 days under controlled conditions.

Density (ρ): Determined according to EN 772-13.

Compressive strength (σ): Measured following EN 1015-11.

Thermal conductivity (λ): Determined using a heat-flow meter method.

3. Results and Discussion

3.1 Physical and Mechanical Performance

The incorporation of recycled plastics significantly reduced the block density, reaching values as low as 500 kg/m³. Despite a cement reduction of approximately 40–50% compared to conventional masonry units, compressive strength values of 2.2–3.0 MPa were achieved, satisfying the requirements for lightweight masonry blocks.

The formation of micro-voids associated with plastic inclusions contributed to improved thermal insulation, resulting in thermal conductivity values below 0.4 W/m·K.

3.2 Optimization of Material Composition

Volcanic ash played a critical role in improving microstructural continuity through pozzolanic reactions, partially compensating for reduced cement content. Crushed brick and basalt aggregates acted as rigid fillers, enhancing compressive strength while limiting density increase.

The experimental results confirm that once binder percolation is achieved, further increases in cement content yield diminishing mechanical benefits while adversely affecting thermal and environmental performance.

3.3 Environmental Impact

Reducing cement consumption directly lowers energy demand and CO_2 emissions associated with clinker production. Additionally, the utilization of recycled plastics diverts waste from landfills and supports circular economy principles within the construction sector.

4. Composition and Performance Data

Table 1.

Composition and Properties of the Developed Blocks

Component	Proportion (%)
Crushed brick	20–25
River sand	10–15
Basalt aggregate	10–15
Volcanic ash	10–15
Cement	10–15
Recycled plastic	15–20
Density (kg/m³)	**500–650**
Compressive strength (MPa)	**2.2–3.0**
Thermal conductivity (W/m·K)	**< 0.4**

Table 2.

Comparative Performance of Masonry Blocks

Block type	Density (kg/m³)	σ (MPa)	λ (W/m·K)	Cement reduction (%)
Conventional concrete block	~1800	12–15	~1.2	0
Proposed composite block	500–650	2.2–3.0	< 0.4	40–50

5. Conclusions

The study demonstrates that construction blocks incorporating recycled plastics and alternative mineral aggregates can:

Achieve lightweight and energy-efficient performance

Reduce cement consumption by up to 50%, lowering CO_2 emissions

Maintain sufficient compressive strength for masonry applications

Comply with European thermal and mechanical standards

Support sustainable construction and circular economy objectives

The developed material shows strong potential for non-load-bearing walls and low-rise buildings where thermal efficiency and environmental impact are critical design criteria

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EXPANDING STUDENT SERVICE CAPABILITIES USING AI: IMPLEMENTING LLM AND RAG INTO UNIVERSITY INFORMATION RETRIEVAL SYSTEMS

Nino Beraia
Doctor of Technical Sciences, Professor
Georgian Technical University
77 Kostava St., Tbilisi, 0160, Georgia
Andrei Bykov
Bachelor of Informatics
SENLA LLC
Przyokopowa 31, 01-208, Warsaw, Poland
DOI: 10.5281/zenodo.18925084

Abstract

Traditional digital technologies in higher education, including official websites and PDF documents, are often fragmented, limited by language, and do not allow for efficient data retrieval, particularly for international students.

This paper presents an approach for integrating Large Language Models (LLMs) and the Retrieval-Augmented Generation (RAG) method into existing university services. The proposed architecture provides semantic search, real-time data updates, multi-language support, and interaction with existing backend applications without the need for model fine-tuning.

A chatbot prototype was developed, allowing students to access information in their preferred language based on up-to-date university data. Testing demonstrated high accuracy in information delivery and a seamless user experience. The proposed approach carries practical significance.

Keywords: Large Language Models (LLM), Retrieval-Augmented Generation (RAG), Digitalization of educational services.

Accessing university information is frequently hindered by several factors. Data is often fragmented, presented in disparate formats (such as PDFs, spreadsheets, and external links), and lacks comprehensive multilingual support. The absence of semantic search requires users to be familiar with the website's specific structure, which poses a particular challenge for international students and undermines the inclusivity of the information environment.

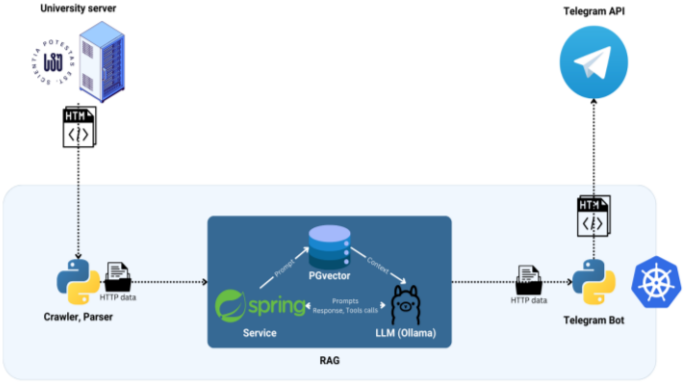
Building on prior research into the digitalization of student services [1, 2], this paper explores the application of Retrieval-Augmented Generation (RAG) and Large Language Models (LLMs) to facilitate intelligent access to university information.

The proposed approach enables real-time retrieval of up-to-date data, remains resilient to variations in user phrasing, provides multilingual support, and generates context-aware responses. Furthermore, the architecture is designed for scalability and seamless integration with existing services.

The novelty of this work lies in the practical integration of LLM-based function calling and RAG within an existing university microservice architecture without fine-tuning, ensuring real-time data consistency.

This work enhances the functionality of a chatbot that enables students to retrieve schedules via a messaging interface. A dedicated crawler service has been added to parse the entire university website using the crawl4ai library, which is specifically designed for LLM data extraction.

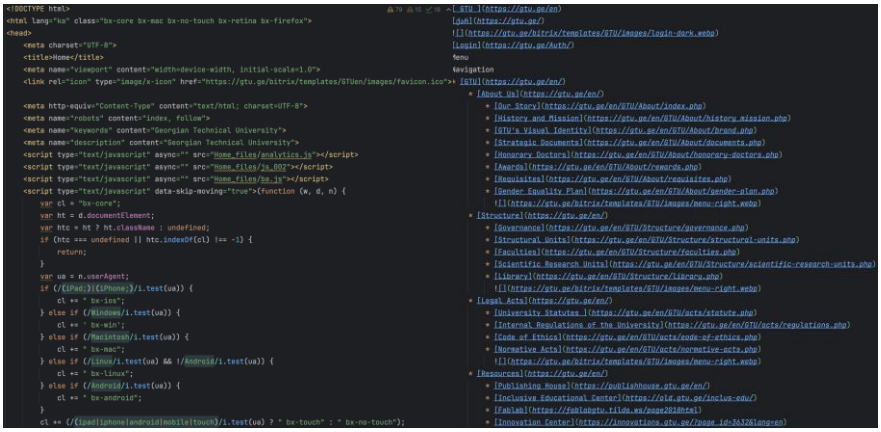
The service integrates a Qwen3 LLM – deployed via Ollama on Kubernetes – into the backend application through Spring AI. Furthermore, the system now supports the invocation of existing methods by the LLM using the "Tools" functionality. The pgvector extension is employed for storing embeddings, while the multilingual bge-m3 model was selected for data vectorization. With the addition of end-to-end chat capabilities to process any user input, the service has evolved into a full RAG system. The resulting architecture is illustrated in pic. 1.



Pic. 1. Application architecture after LLM integration

During the data crawling process for LLMs, information must be partitioned into chunks and stripped of HTML and other code while preserving the original text's structural elements, such as tables and headers. A comparison between the university homepage source code in HTML and Markdown is presented in pic. 2. Despite the significant reduction in character count, the structural integrity of the website's information is maintained.

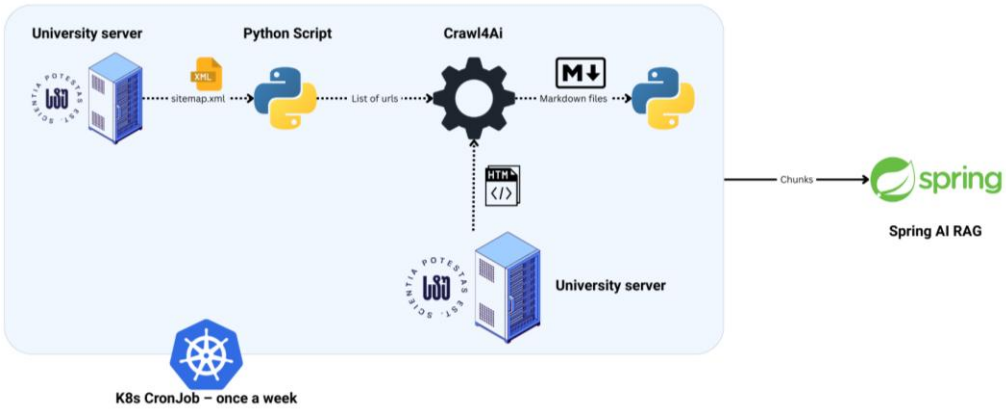
The crawler operates according to the following algorithm. First, the system identifies page URLs; for the Georgian Technical University, the existing sitemap is easily parsed for this purpose. Next, crawl4ai downloads the HTML pages and converts them into Markdown.



Pic. 2. gtu.ge html and markdown formats comparison

The formatted data is then partitioned into chunks for the LLM. Using a combination of header-based splitting and fixed character counts ensures consistent segment lengths. Finally, these processed text fragments are sent to the RAG service for storage in the vector database.

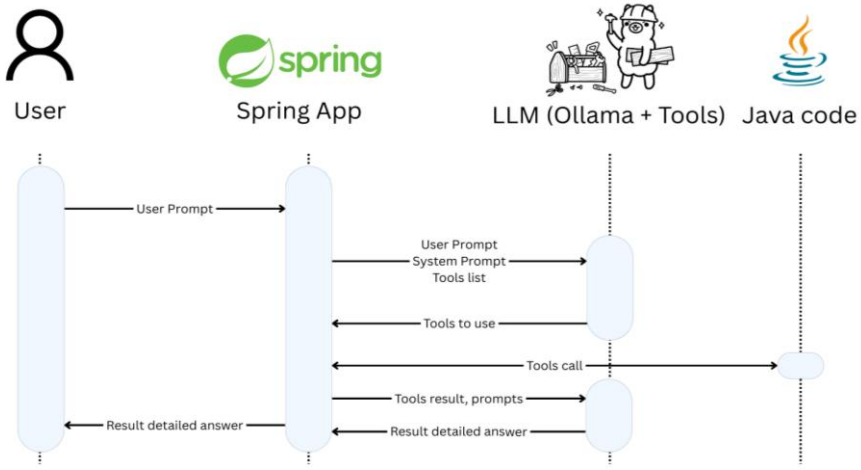
Since web crawling is an expensive operation, the system monitors sitemap.xml for updates using hashing. Execution is managed via a Kubernetes CronJob to ensure data remains current. The crawler architecture is illustrated in pic. 3.



Pic. 3. gtu.ge crawler architecture

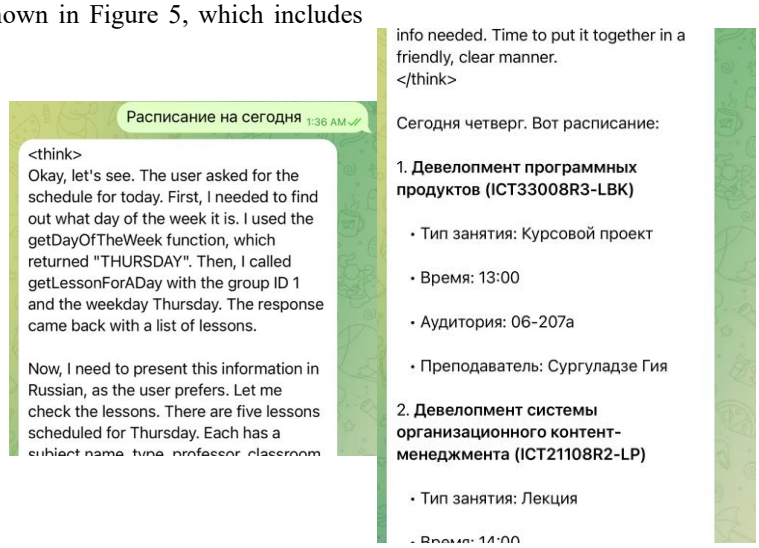
The project originally featured a schedule function, allowing registered users to view group timetables via button interfaces. Using Spring AI, adapters were developed to make these functions accessible to the LLM. Each method includes English-language descriptions of its purpose and parameters. Consequently, three specific Tools were implemented: a general utility to get the current day of the week, helping the model orient itself in time; a function to get classes for a specific day by group ID, utilizing the day provided by the previous tool and the group ID from the user context; and a function to get classes for the entire week by group ID, which requires only the group ID.

The resulting lifecycle operates as follows: the user submits a query; the library passes this query, the system prompt, and the available toolset to the LLM; the LLM determines the necessary actions and returns execution data; the application code is executed; the LLM receives the results along with the remaining context; and finally, the LLM generates the final response. The simplified interaction architecture is shown in pic. 4.



Pic. 4. Tools interaction architecture in GTU system

Consequently, the LLM receives reliable data through direct code execution, allowing it to focus on minimal data selection tasks. An example of a real-world use case is shown in Figure 5, which includes the model's "reasoning" process. In this instance, the user requested a schedule in Russian and received a formatted response.


Расписание на сегодня 1:36 AM
<think>
Okay, let's see. The user asked for the schedule for today. First, I needed to find out what day of the week it is. I used the getDayOfTheWeek function, which returned "THURSDAY". Then, I called getLessonForADay with the group ID 1 and the weekday Thursday. The response came back with a list of lessons.
Now, I need to present this information in Russian, as the user prefers. Let me check the lessons. There are five lessons scheduled for Thursday. Each has a
info needed. Time to put it together in a friendly, clear manner.
</think>
Сегодня четверг. Вот расписание:
1. Девелопмент программных продуктов (ICT33008R3-LBK)
• Тип занятия: Курсовой проект
• Время: 13:00
• Аудитория: 06-207a
• Преподаватель: Сургуладзе Гия
2. Девелопмент системы организационного контент-менеджмента (ICT21108R2-LP)
• Тип занятия: Лекция

Pic. 5. An example of using the Tools

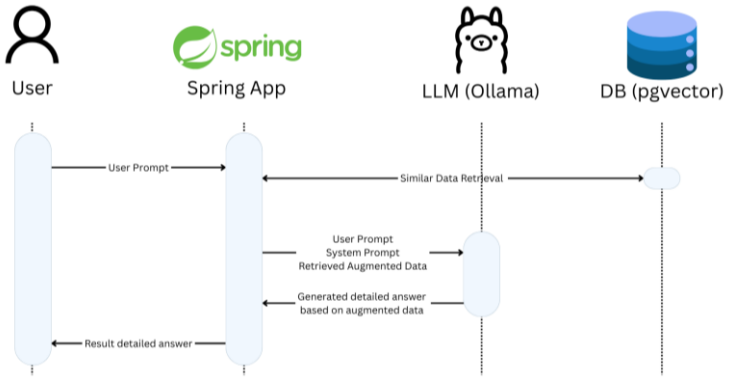
The university website contains too much data to include in every model request; due to context window limitations, the LLM cannot process all information simultaneously. To address this, website data is converted into embeddings. The capabilities of embeddings, along with the specific challenges and solutions implemented in this project, are summarized in Table 1.

Table 1

RAG Capabilities, Challenges and Potential Solutions

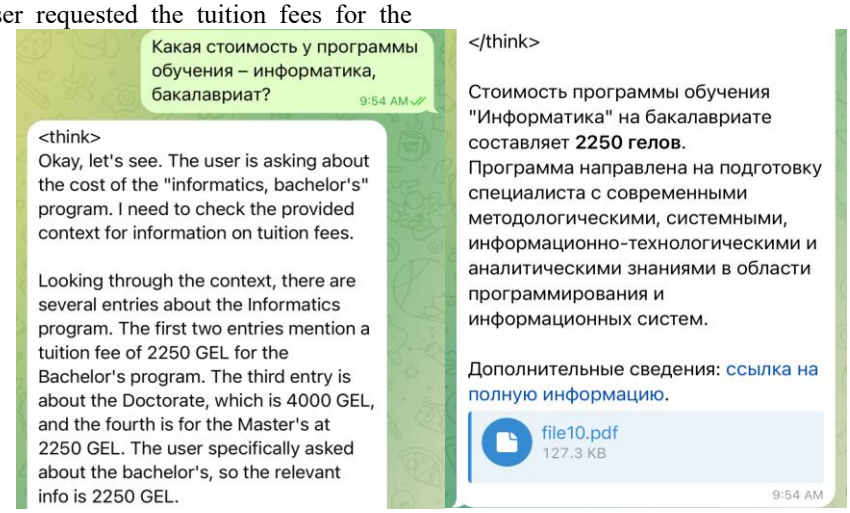
Capability	Challenges	Solutions
Semantic Similarity Search	Multilingual semantic equivalence; large volumes of similar data overflow context or create contradictions; models may prematurely claim data is missing if the initial search returns no results	Utilizing multilingual embedding models to align similar meanings in vector space; strictly limiting the volume of retrieved data; using system prompts to "motivate" the model to search through other tools
Vector Representation	Vectors are non-traditional data types for relational DBMS and conflict with the First Normal Form (1NF)	Implementing extensions for popular relational databases, such as pgvector, or utilizing dedicated vector databases
RAG Output Generation	Risk of providing incorrect data (e.g., PhD info for Undergraduate queries) or users trusting unverified information	Attaching metadata (URLs, timestamps) during ingestion and requiring the model to cite these sources in its final response

In the implemented system, RAG retrieves data similar to the user's query before the LLM is invoked. This information is then appended to the original query and sent to the LLM. The model must determine which specific data points to use and, guided by the system prompt, include all necessary references in the final response delivered to the user. A simplified diagram of the RAG interaction within this project is shown in Figure 6.



Pic. 6. RAG interaction scheme within the university information system

A real-world example is shown in Figure 7, where part of the model's "reasoning" process has been included for demonstration purposes. In this instance, the user requested the tuition fees for the undergraduate informatics program in Russian and received a detailed response including a direct link to the source.


Какая стоимость у программы обучения – информатика, бакалавриат?
9:54 AM
<think>
Okay, let's see. The user is asking about the cost of the "informatics, bachelor's" program. I need to check the provided context for information on tuition fees.
Looking through the context, there are several entries about the Informatics program. The first two entries mention a tuition fee of 2250 GEL for the Bachelor's program. The third entry is about the Doctorate, which is 4000 GEL, and the fourth is for the Master's at 2250 GEL. The user specifically asked about the bachelor's, so the relevant info is 2250 GEL.
</think>
Стоимость программы обучения "Информатика" на бакалавриате составляет 2250 гелов.
Программа направлена на подготовку специалиста с современными методологическими, системными, информационно-технологическими и аналитическими знаниями в области программирования и информационных систем.
Дополнительные сведения: ссылка на полную информацию.
file10.pdf
127.3 KB
9:54 AM

Pic. 7. End-user interaction with the RAG system

This research confirms the feasibility of integrating LLMs and RAG into university information systems without requiring model fine-tuning. However, system performance remains heavily dependent on model quality, data preprocessing, and infrastructural capacity. The risks of hallucinations and incomplete retrieval continue to pose significant challenges.

The university's intelligent information system successfully met its objectives and validated the proposed concept. Future work will focus on establishing a metrics system to monitor user behavior, specifically tracking the adoption rate of the LLM-based interface, error frequency, and the types of queries that prove most challenging. Additionally, a feedback mechanism will be implemented to assess the accuracy of the retrieved information. These collected datasets will provide a basis for evaluating the scalability of such systems at the current stage of generative AI development.

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